THE ADVANCEMENT OF SCIENCE

VOL. I. No. 3 APRIL, 1940

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NOTE ON COMMUNICATIONS TO THE SECTIONS

Dundee Meeting, August 30–September 1

When the Dundee Meeting was brought to a close after three days, it was decided that all communications of which the delivery was unavoidably cancelled should be taken as read. Abstracts (or titles) of communications are therefore printed in these pages whether the communications were delivered or not, and references to dates and hours, as furnished in the Journal issued at the Meeting, are excluded.

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It is intended to supply an index to the four parts in each year, in the July issue.

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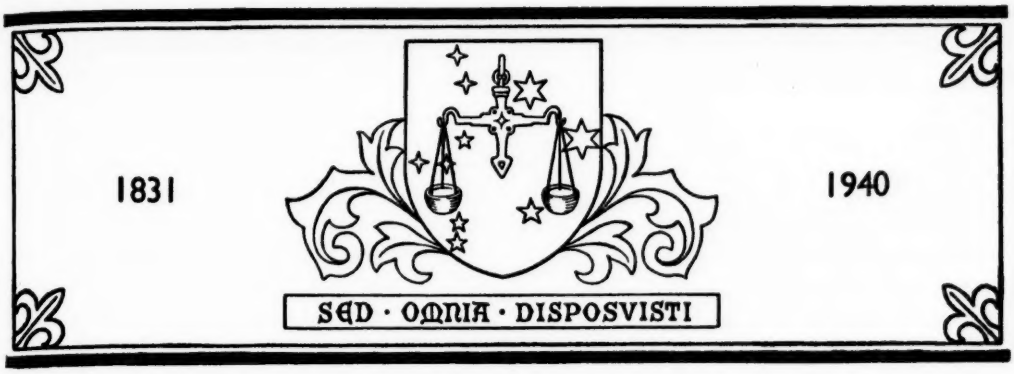

THE ADVANCEMENT OF SCIENCE

NOTES

In the preceding issue of The Advancement of Science it was stated that the General Committee had instructed the General Officers to arrange a short Conference at a suitable place, in lieu of the appointed Annual Meeting in the present year. It is now possible to announce that, subject to unforeseen circumstances, a Conference will be held by the Association in the University of Reading, by kind permission of the Council of the University, from Thursday, July 25, to Saturday, July 27, under the Chairmanship of Sir Richard Gregory, Bt., F.R.S., President of the Association. It is contemplated that the Conference should last for an afternoon, a full day, and a morning. It is called a Conference to distinguish it from the usual Annual Meeting. The Conference, in general terms, will deal with Science in National and International Aspects.

It is not contemplated that the usual Sections should meet individually unless reason should emerge for any of them to do so ; nor is it intended to make the usual appointment of new sectional officers.

It is proposed that after a short opening general session the Conference should divide into groups sitting concurrently. For such groups, four general headings have been formulated :—

(1) International Intellectual Co-operation.
(2) Natural Resources and National Needs : (*a*) Minerals, (*b*) Plant Products.
(3) Social Aspects of Human Nutrition. (Not necessarily confined to this country).
(4) Scientific Discovery and Progressive Industry.

The first and third of these subjects would have been dealt with by the Division for the Social and International Relations of Science at the Dundee

Meeting last September if that meeting had not been brought to a premature close.

These groups together cover a wide field, and communications in various departments of science will find places in one or other of them ; but communications appropriate to the Conference, though outside the range of the groups, may also be included.

Full particulars of the Conference and arrangements in connection therewith will be issued in due course.

* * *

The small permanent office staff of the Association has been reduced by the withdrawal of the assistant secretary, Mr. D. N. Lowe, for service in the Ministry of Supply, and of Mr. A. J. Faulkner, assistant clerk, in order to join the N.A.A.F.I.

* * *

The present issue of THE ADVANCEMENT OF SCIENCE is necessarily reduced in bulk in comparison with Nos. 1 and 2, owing to the rationing of paper, as well as to financial considerations. It had been intended to complete the publication of material relating to the Dundee Meeting in this issue ; but it has now been found necessary, and on other grounds desirable, to hold over to No. 4, the July issue, the transactions of Section L (Education), which, in addition to Dr. A. P. M. Fleming's presidential address and abstracts of communications, will include the important reports of the committees on Educational Research and on the Informative Content of the School Curriculum. It is hoped also to publish in the next issue the British and American Association Lecture, which should have been delivered at the Dundee Meeting by Dr. Isaiah Bowman, president of Johns Hopkins University, U.S.A., on Science and Social Pioneering. This would have been the first lecture under the arrangement concluded in 1938 between the British and the American Associations for the Advancement of Science, by which, in alternate years, an American speaker should address the British Association, and a British speaker the American Association.

* * *

The grounds of Down House, Darwin's home at Downe, Kent, which is preserved by the Association as a national memorial under the gift of Sir Buckston Browne, F.R.C.S., were reopened to the public from Good Friday last, between 10 A.M. and 6 P.M. The Darwin memorial rooms in the house remain closed to public access.

RATES AND TAXES

ADDRESS TO SECTION F.—ECONOMICS

By Prof. H. O. MEREDITH

PRESIDENT OF THE SECTION.

In searching for a subject upon which I might venture to address you I was attracted to public finance by a number of considerations. Of these the most important were : first, that we meet here issues which in a high degree are controllable at will ; within limits we can decide, both what proportion of the national dividend shall be appropriated and spent by public authority, and how the total contribution shall be subdivided between individuals. Secondly, having this power of choice we have also a serious responsibility for its exercise : there is no such thing as a neutral financial policy ; we are bound to do this or that, and the implications of this differ from the implications of that in terms of soul and body. Thirdly, it would seem that action in this field is not wholly beyond the reach of argument : passion, no doubt, counts for much ; conservatism for more ; idleness, hurry, inconsequence for most ; but financial authority does sometimes betray discomfort when confronted by reasoning which it is incompetent to answer ; exceptionally we may even encounter a ' poor fish ' like Peel, who crumpled up his notes while Cobden was speaking and muttered to a colleague that someone else must reply. Lastly and more dubiously, I thought that I myself had something to say on this topic, little as I might relish the prospect of saying it.

Let us begin by reminding ourselves that the main drift of social and economic evolution seems to portend a persistent increase in the ratio of public to private expenditure. If we are to continue to fight and to prepare for fighting, that goes, almost, without saying. It would, however, probably occur even if we found a way out of war ; indeed, it might well be a necessary factor in the discovery of a way. It seems, in a word, certain that a larger and larger proportion of man's energy will be expended, as time goes on, in ways and for purposes whose cost cannot be financed by the sale of discrete *quanta* to individuals and must therefore be covered by more or less voluntary contribution. Purely voluntary systems of association can, it is true, do something in these fields ; in the past that something has been much. But the broad teaching of experience in this matter shows that voluntary association is useful chiefly at the stage of initial experiment and in relatively minor undertakings. When it comes to mass-education, mass-insurance, mass-provision for recreation, drainage, or what not, the element of compulsion is as unavoidable as in the case of mass-war.[1]

[1] It is sometimes supposed, and superficially the view is not unplausible, that much of this tendency is a corollary to income inequality, and that the movement would weaken

Next it is to be remembered that this persistent increase in the ratio of public to private expenditure implies in two ways a parallel increase in the importance of determining the distribution of taxation throughout the community accurately and in accordance with principle. In the first place an appreciable part of the *raison d'être* of the process is the need to modify the allocation of income which results from contract, ownership, and inheritance. It is universally agreed that part of our financial objective is to reduce in some measure the discrepancy of real income between rich and poor. How far we want to go in this matter is, of course, disputed and must probably always be disputable, but to the extent to which this purpose is admitted its logic must condemn any element in our system which opposes it and be critical of any element which in regard to it is random or uncertain in its action. And secondly, the mere increase in the proportion of income arrogated to public purposes enhances disproportionately the evils of random taxation. When I am only asked for two per cent. of my income it matters little if, from the point of view of either equity or economy, that two per cent. ought to have been one. There will, on the other hand, be an enormously important difference if, when my proper contribution is twenty-five per cent. of my income, I am asked to pay fifty.

If we approach our actual practice with these considerations in mind, the examination of a representative budget statement and debate becomes a somewhat alarming and deeply humiliating experience. It is evident always, in the first place, that all parties concerned are definitely *frightened* of taxation. One can almost *hear* the sigh of relief when in an hour of alleged and apparent national emergency it is found possible to evade an addition of threepence to the income tax. The whole language of financial discussion is suffused with the feeling that taxation is a bad thing, and not only a bad thing but one which we do well to run away from. Secondly, we may note always a lamentable incuriosity both as to where, broadly speaking, the burden of taxation (if it be a burden) rests and what its effects are, together with an impatience of any endeavour to probe into these questions. There are, it is true, certain venerable traditions to which appeal is made with all due solemnity—and brevity. It is an axiom, apparently, that both direct and indirect taxation should 'bear their share,' but no considered discussion takes place as to what these shares ought to be. It is again an axiom that taxation in general, and the income tax in particular, are 'bad for trade.' At this point, also, no undue cackle is tolerated ; our governors are too anxious to come to their horses—to discover as quickly as possible with just how little alteration of the existing system the situation may be tided over for one more year. Briefly, the characteristic note of budget-discussion is a certain glum frivolity. There is an evident, and to do our House of Commons justice a *curious*, lack, in this particular field, of the intellectual and moral courage which in other quarters it displays.

greatly if incomes were equalised. It is, I think, evident that if incomes were equalised by a return to more individual methods of production and tenure of property, the functions and cost of government would be alike restricted. If, however, the goal were approached without abandonment of collective and co-operative technique, I should anticipate the converse. The smaller the range of inter-class standards of living the more easy would it become to discover objects to which that technique could be applied, and the less would be the obstructive force of disparate aims and interests.

A central difficulty is, undoubtedly, that although we have adopted many of the forms of democracy, citizenship retains in regard to taxation something of the sentiment which belongs to servile status, while government has not quite discarded the mental habit of predaceous authority. Our representative citizen does not enjoy paying taxes ; if opportunity of evasion within the law presents itself he avails himself thereof ; if it does not present itself he will hire specialised ability to discover it ; finally, he is none too scrupulous in seizing opportunities which are definitely beyond the law. Unquestionably this distaste for taxation goes far to explain, and even in some sort excuses, the miserable figure which our financial system cuts : every Chancellor of the Exchequer knows that the feeling of the House will be with him in every argument evasive of immediate increase in expenditure or taxation. To what are we to ascribe this recalcitrant temper ? It is convenient to distinguish three strains in its genesis. First and most obvious is the fact that the modern State still is appreciably predatory, the representative citizen still does occupy a quasi-servile position. This is an evil which can be cured, if at all, only with time and by persistent effort. I shall remark, however, that in so far as it exists it seems specially important to make financial principle explicit, to show the representative citizen what he is doing in this matter to others or others to him. Only one tentative movement has been made in this direction during my lifetime, namely, the official estimate some ten years back of the weight of taxation at different points in the income scale. This calculation showed, it will be remembered, that our taxes are regressive on the lowest incomes, a necessary consequence of attacking those incomes by indirect taxation. A further and more important element of regression is involved in our local rates taxation, and in the compulsory contributions to health and unemployment insurance. The official enquiry raised, perhaps, more questions than it answered, but why has the matter been dropped ? Why is not every budget statement accompanied by a memorandum explaining broadly the relation of the taxes proposed to the national totals of wealth and income and the ratio of taxation to income at different points in the income scale ?

Secondly, there is the inevitable limiting factor of individual defect. It is not easy for a man to face his civic obligations as honestly as he faces his butcher's bills, because in the nature of the case he cannot see them as clearly. Men cheat the Government, much as they cheat a railway company, not only because they dislike or fear it, but simply because it and its doings are beyond their power of comprehension and sympathy : their relations with it are too amorphous, too indirect, too indistinct. This factor, also, is controllable, if at all, only with time and by deliberate effort. To create the sense of citizenship where the concept is non-existent is the master problem of statesmanship. In this case also, however, it would seem that one method of progress would be to confront the representative citizen with fuller and clearer statements of what financial policy is and what it implies in relation to his own income and the incomes of other people.

There is, however, I would suggest, a third by no means unimportant strain in our dislike of taxation which may be more amenable to argument, namely, the tradition that public expenditure is costly in some further and fuller sense than are private disbursements. The existence of this feeling is unquestionable. All debate in Parliament, all discussion in the press, is suffused

with suggestion of that ancient fallacy, the distinction between productive and unproductive labour, and its corollary that the incomes of those who are employed by the State are derivative from the product of industry. Seldom do we encounter the clear-cut view that activities of government co-operate on an equal footing, to say the least, with activities of private enterprise in generating the national dividend. Everywhere we can trace remnants of the ghastly Gladstonian doctrine that money should be left, where possible, to 'fructify in the pockets of the people.' Other things being equal, of course it should : yet equally should it be brought, where possible, to fructify in the coffers of the State. Actually, money will not fructify if it is left either in pockets or in coffers ; it will merely weight the swimmer down or sink the ship. Gladstone expressed his meaning with customary clumsiness and inaccuracy. What he really had in mind was money springing nimbly from pocket to pocket, promoting prosperity by its leaps and bounds. It may, however, travel no less nimbly when it has been expended by the State.

Victorian finance, with all its obvious defects of imagination and emotion, had the sovereign virtue of logical cohesion. Granted the major premise of *laissez faire*, that the State is only necessary for the restraint of evil conduct at home and ill-will abroad, a decision to reduce taxation to a minimum and to raise that minimum by duties on stimulants and sedatives has much to commend it. For if the less government the better, then obviously also the less public expenditure the better : *ergo* minimise taxation. And if such government and taxation as are required are rendered necessary by vice : why should the virtuous citizen contribute anything ? May he not reasonably argue that if all men were as he is there would be no need for even the minimum of government and taxes ? Is it not reasonable, then, to raise revenue exclusively by duties on forms of consumption which are vicious or allied to vice, like the smoking of tobacco and the drinking of alcohol or tea ? If, lastly, it be objected that the virtuous should at least contribute to defence against external ill-will, it may be answered that it is the vicious in all countries who occasion war and preparation for war, and that justice will be done on balance if all countries raise their revenues exclusively from the less virtuous of their citizens.

These arguments have never, perhaps, been advanced deliberately and in their full enormity by any responsible person : on the other hand, not very many of us succeed in avoiding them altogether. Indeed, it may be well to consider, before going further, whether there is not so much of sense in them as might justify us in retaining them not indeed as the basis of our system of taxation but as an auxiliary support ; for the feeling is common enough in men of all classes that the State owes more to them than they to it, and that, therefore, anyone rather than themselves ought to contribute to its expenditure. This attitude I have noted more particularly in elderly bachelors and spinsters and in widows of moderate means, who are comfortably off but inadequately occupied or interested. It is evidently in such cases as theirs that it is most nearly defensible, for it is these individuals, in general, who have obtained least satisfaction from lives indisputably virtuous. Nevertheless, it must be insisted, relief from taxation is not the right remedy in this and in analogous cases. In so far as their grievances are material tax relief would be in its total inadequate, in its subdivision indiscriminate ; in so far as they are spiritual, pecuniary compensation is inappropriate. The same dilemma may

be pressed, I believe, more broadly, against all those who believe that their virtue entitles them to evade taxation. We must ask them to take more seriously the view, so often enunciated, that virtue ought to be its own reward, as also the less popular corollary that vice should be its own penalty. We should remind ourselves, further, of the enormous *practical* wisdom which is enshrined in those esoteric doctrines : all actual estimates of virtue and vice must always be too largely subjective to furnish in a democratic community a satisfactory scheme for the distribution of taxation.

Victorian finance in England was, we have suggested, a logical outgrowth from the doctrine of *laissez faire*. Our trouble is that while abandoning that doctrine we have never seriously set ourselves to think out financial principles comparable in their logical cogency with those which guided Gladstone. Our tradition retains, no doubt, some valuable legacies from the past, notably a certain sobriety in experiment and a rugged exactitude of accounting : these virtues, however, in so far as they are virtuous, are formal ; they nowhere touch the essence of the matter ; it is as though we had no sense either of where we want to go or of how to get there, but merely certain rules of the road and a speed limit. One result of this atrophy of living principle is that whereas the Victorians were capable upon occasion of really large measures of reconstruction in advance of the pressure of necessity, our finance seems more and more to make that fatal error of strategy—conforming to the enemy ; instead of grasping nettles we wait until we are stung. It is true, no doubt, that the Victorians were concerned primarily with retrenchment, and that it is always easier to scrap than to build, yet it will probably be conceded that we are, in financial policy, increasingly passive and show ourselves less and less capable of vigorous initiative. Alterations in our tax system become more and more a matter of yielding to pressure rather than of constructive planning : it follows incidentally that where that system bears with undue hardship on individuals a large measure of oppression must occur before any relief is accorded ; and further, that what relief is granted more frequently resembles a sop to Cerberus than an orderly rationing of food. The troubled conviction that something has got to be done which issues from an atmosphere of desultory grousing is apt to generate measures which combine a minimum of relief at points where it is really needed with a maximum of expense to the State. Let us illustrate these remarks by considering two cases : first, that of the income-tax allowance in respect of children, secondly, that of de-rating.

The initial relief in respect of a child exempted £10 from income taxation at a time when the tax stood at 9*d.* in the pound on earned incomes. I do not remember to have seen it remarked at the time that this worked out at 7*s.* 6*d.* per child per annum, the very figure which was at the same time in England the cost of a dog licence. We have advanced since that date to £60 per child, which, with tax at 5*s.* 6*d.*, yields the princely sum of £16 10*s.* per annum, approximately 6*s.* 4*d.* per week for income subject to the full rate of 5*s.* 6*d.* in the £, but of £5 only (2*s.* per week) for income subject to the 1*s.* 8*d.* rate. Allowance being made for rise in the standard of child welfare since the war these figures are divertingly reminiscent of Mulvaney's taunt to his sergeant : ' squawlin' on a counterpane at half-a-crown a week.'

What was the *raison d'être* of this curious gesture to parents ? Presumably it was a concession to a vague feeling that something should be done to ease

the expenses of those who rear children. But is such easement required, and, if so, in what circumstances and to what degree? We must suppose it to be assumed by those who have been responsible for these measures that a married couple with children is at any grade of income worse off than a married couple without children. If we take the extreme case of a family with six or more children this is evident. The income which implies plenty for two may infer penury for eight. If we take, on the other hand, the minimal family of three it is by no means obvious. Very little knowledge of actual life is needed to stir the suspicion that average humanity gets more satisfaction from what it spends upon a single child than it could derive in the absence of the child from spending the same sum in other ways. We might, in fact, develop a case for charging childless couples somewhat less than their more fortunate fellows, and might even extend this argument to two, conceivably to three children, without becoming palpably absurd. Few couples, we suspect, deliberately limit their offspring to less than two if they are willing to procreate at all, and it is certainly not the income tax allowance which prevents their halting at one: its ratio to the cost of a child is obviously far too small to affect the decision in the vast majority of cases. What this boils down to is that through obeying the vague sentiment that something ought to be done, without seriously considering what we are about, we have drifted into the absurd position of wasting on small families (the vast majority of cases are small) sums of money far more than sufficient to give ample relief to large families, while according to our small number of large families a relief which is ludicrously inadequate to its presumable purpose. There was even a time when the relief on a first child was greater than the relief on a second or third. That crowning absurdity has been removed, but the fundamental stupidity of the whole scheme remains unaltered.

Let us consider next another feature of the scheme, namely, that it makes, after the first few hundreds have been passed, no differentiation in the amount of relief at different scales of income. If it be admitted that the object of the system is to relieve appreciably the family with many children as compared with the family with few, we have here a second absurdity: for a sum which at one level of income would be adequate to this purpose will evidently be inadequate at another. What is the use of presenting £16 to a man who is spending perhaps £150 per child if your object is to promote larger families in the upper half of the income scale: families of four to six in place of families of one to three children? It is a pill to cure an earthquake. Can any sane person believe in such nonsense? It is the perfect parallel to our practice of fining individuals without regard to their incomes, so that a given offence may send a poor man to prison for a month whilst a rich man escapes at something less than the cost of an evening frittered in town.

We turn now to de-rating. And here we must beware of taking surface absurdities at their face value, and supposing that no serious reason can exist for policies fallaciously defended. The popular case for de-rating rested on appeal to the naïve misconception that agriculture, industry and transport are more productive than commercial and professional services, entertainment, and housing. This factor was re-enforced by a sense of the temporary embarrassment of our staple industries and the chronic difficulties of agriculture. Viewed whether as temporary relief or as a permanent subsidy the procedure was partly too indiscriminate, partly inadequate. Viewed as a semi-authorita-

tive endorsement of the notion of higher productivity the policy should make us blush. It had, however, an esoteric justification which deserves consideration. The central problem of local finance is to devise suitable forms of local taxation, to attack in each locality those incomes which may properly be drawn upon to defray the special requirements of that locality. The difficulty of this problem hinges, in turn, upon the fact that there are *no* incomes (in a modern state) which are wholly and solely local in the relevant sense. It is a question therefore of choosing between sources of revenue which are adequately and those which are inadequately local. Now it does seem broadly true that the incomes implicated in rating of agriculture, industry and transport are in the modern world increasingly non-local. The fact that a given agricultural area has through proximity to London high productive power in dairying or the growing of fruit and vegetables gives London rather than the area a claim to its taxation. Mines, factories and railways are even more evidently unsuited to local taxation. And, on the other hand, the bulk of housing and of retail trade and entertainment, together with a large proportion of wholesale trade and professional services, are as evidently local in their main implications. We might accordingly defend the de-rating scheme esoterically, as a decision to extrude from our system of local taxation elements obviously unsuitable to it whilst at the same time increasing the proportion of central government grants for local purposes in accordance with the ever-growing integration of local and national life.

Are we then in contact with one of those cases, so familiar to students of Economics, in which approximately the right course has been taken for approximately the least valid reasons? It is impossible, unfortunately, to maintain this optimistic view. So long as concrete capital and land are taxed at all, there are grave objections to exempting any part of them from taxation. On the one hand de-rating must encourage transfer of investment from those forms of property which continue to be rated with presumptive loss to the national dividend. And on the other hand, whether we consider the beneficial or the onerous aspect of public expenditure the de-rated properties, taking the community as a whole, obtain benefits for which they should pay, and impose costs to which they should contribute. It is accordingly evident that so long as local rates are continued on other forms of capital, properties de-rated locally should pay a consolidated national rate into a national pool.

If we turn now to consider, broadly, what if any part of our financial system can be approved in principle and seems to be suitable for development, I suggest with some confidence that our main direct taxes, income-tax, sur-tax, and death duties, are our only unassailable sources of revenue. Not, of course, that any or all of them stands beyond criticism: each of them may be blamed on points of detail. There is, however, I should maintain, a sufficient *communis opinio* that they are all desirable and (what is at least as important) all of them can be defended by serious arguments. Income *is* in fact the best rough measure of capacity to bear taxation; capacity to bear taxation *is* proportionately greater with a large income than with a small. These axioms give us a valid basis for progressive income-tax and sur-tax. And again, those who inherit can usually bear taxation, *pro tanto*, more easily than those who do not inherit, while there are weighty reasons for limiting the

tendency of hereditable wealth to increase the inequality of distribution. The most serious objection that has been urged in the past against all these taxes is their alleged tendency to inhibit accumulation. This objection seems never to have been really cogent during the past century and a half. To-day it is no longer even plausible in view of the tendency for desire to save to outstrip the possibilities of advantageous investment.

The axioms which are generally accepted as validating these taxes create however, at once, an initial presumption against our other main sources of revenue, the indirect taxes on commodities and the local rates. For these taxes are admittedly, when looked at from the point of view of income, regressive in a high degree. They have, further, no appreciable relation to windfall or unearned increments of wealth, and they intensify rather than diminish inequality. There are, of course, elements in each of them of a different character. Customs and Excise duties are taxes not on all income expenditure but on certain modes of consumption which are for various reasons alleged to be, relatively speaking, unnecessary, deleterious, or noxious. Local rates again do not, in all probability, fall wholly upon purchasers of goods or services derived from rated property and the inhabitants of rated dwellings. In part they intercept income which would otherwise pass *via* land values to hardly traceable recipients ; they may also conceivably take some small toll of interest. Finally, taxes on commodities have long been defended as the only possible way of reaching certain incomes which ought to be taxed and which, it is alleged, cannot be reached effectively by direct taxation. Rates are analogously commended as the least bad way of financing local autonomy. We have then to examine what weight may reasonably be assigned to these considerations.

The taxation of commodities was not perhaps always so ridiculous as it appears to be to-day. So long as trade was a mere excrescence or fringe upon a predominantly local productive system there was some sense in adding to the cost of commodities which the King's peace enabled to be transported a part of the cost of maintaining that peace. Again, when consumption was largely standardised for each class and graded from one class to another it may have been possible by suitably adjusted taxes to achieve approximately a progressive taxation of income. In the eighteenth century, for instance, it is not wholly impossible that taxes on tea, alcoholic beverages, silks, lace, armorial bearings, windows, and men-servants operated partly, in this way, It is indeed to be doubted whether the whole system of commodity taxation could ever have been justified on these lines after the sixteenth century. The main force behind it in the last three centuries has been, almost unquestionably, the desire of the well-to-do classes to detax wealth or minimise its taxation. It is characteristic of the difference in national temper between England and France that whereas in France the aristocracy asserted a privilege of exemption from direct taxation, in England property was content to establish and exercise a constitutional right of exempting itself. An intuition that there ought to be no direct taxes gathered force throughout the sixteenth and seventeenth centuries. In the eighteenth century we piled up debt rather than face taxation until the mounting total of interest put Government to the choice between *seisachtheia* and a proportional income tax. The income tax was abolished as soon as Napoleon had been settled with, and though re-imposed

by Peel its right to existence was questioned by so representative a man as Gladstone as late as the 'seventies. There was, indeed, as some of us can still remember, no serious taxation of income until we were well into the years of the Great War, whilst Harcourt's death duties, so marvellous at the time, create in retrospect the wonder that they were delayed so long and were so insignificant.

These historical considerations should, I think, induce caution in accepting at face value any of the traditional arguments in defence of our taxes on commodities. We should remind ourselves that at the time when they were formulated the governing class had a sinister interest in believing them. We should remind ourselves further of the extent to which they have been buttressed at some important points by puritan fanaticism. Let us turn for a moment to consider the argument which represents the duties on tobacco and drink as an admirable, if not necessary, method of regulating undesirable consumption. In my own case, and I speak with forty years' experience of nicotine-excess, the heavy taxation of tobacco has effected just nothing. I do not smoke one cigarette or pipeful the less because with every puff I contribute to the revenue. What is true of myself seems further to hold, broadly, throughout society. Both men and women appear to smoke more and more as time goes on and the taxes on tobacco rise.

Drinking, on the other hand, and more particularly moderate drinking at meals, has unquestionably declined. There are, however, other reasons for this, and the extent of excessive drinking is still notable in all ranks of society. Briefly it is evident that as a method of limiting undesirable consumption taxation is a 'wash-out.' Its effect is to penalise, not to restrain. If there were any serious intention to promote temperance by control it must operate by attempts to improve the quality and environment of consumption, and probably also by rationing. It may even be doubted whether the taxes would be kept as high as they are, still more whether they would ever have become so high, had elasticity of demand (the index of the restrictive effect of taxation) been adequate to reduce their yield. The pea would then be shifted to another thimble ; we should hear less of the moralising value of these taxes and more of their importance as revenue producers.

The argument from morality is, it should be conceded, more of a force in reserve for the support of these taxes than their first or even second line of trenches in actual debate. The main argument is that they bring money in, and while admittedly inequitable are not much felt, roughly what one hears a man say when he has evaded the income tax or swindled a railway company. That they bring in money is beyond denial, but what, if any, truth is there in this doctrine that they are 'not felt'? If in fact we smoked or drank appreciably less because of them, or if our women wore less silk, there might be something in it. In so far as the delight of luxury expenditure is dependent upon distinction, then, if everyone scales it down in proportion, the delight continues unabated. It is true, of course, that the search for objects of universal or even general luxury consumption has become illusory : we gratify our taste for luxury in too differentiated a fashion. But, waiving this point, in so far as demand for these things is inelastic, the taxing of them *does* impose a burden, it restricts our consumption of other things. We must not now at this point shift the pea under yet a third thimble by pontificating that 'of course'

taxation is onerous. If a burden is imposed these taxes are condemned by their inequitable distribution of that burden. Let us notice also, at this point, their occasional tendency to penalise some of the least happily circumstanced members of society. It is an unpleasing thought that the family of a whisky addict may have to choose between his contributing ten or twelve shillings a week to taxation at the expense of their food and firing, or turning to some cheap substitute such as methylated spirit or coal-gas bubbled through milk. Doubtless women ought to select their husbands more wisely, and children their fathers with even closer prevision, yet when all due care has been taken mistakes must still be made.

What holds in the extreme of drink and tobacco seems to hold generally of all taxes on commodities. We cannot regard them otherwise than as an excessively inequitable and random method of raising revenue. But what of the argument for them as the only available method of levy on a class which ought to contribute? This was the contention, if I remember right, to which Marshall attached importance, though he was always careful to add that whatever we took by taxation from the poorer classes should be returned and more than returned in beneficial State service to them. I feel that this argument is exceedingly relative to place and time together with the parallel reasoning in favour of a general customs tariff as a financial resource in communities where for one reason or another direct income taxation may be unworkable. So far as our own place and time are concerned, I rate its force as negligibly small. The technique of income taxation needs improvement, but it has improved and is improving, while the whole drift of social evolution is persistently reducing the fraction of national income which cannot be attacked directly. So far for the contention that members of the middle and upper classes who evade direct taxation are caught by duties on silk or wines or whisky. As regards the wage-earning class, the plausibility of the argument was weakened irreparably thirty years ago by that ingenious device for taxing wages regressively—the stamped card. It is true, no doubt, that despite all extensions there are still a number of small incomes which escape that net and that the final step of linking it up with income taxation has yet to be taken. In principle, however, the situation is sufficiently clear. It is abundantly proved that direct imposts upon the poorest of the poor are by no means administratively impossible.

Turning now to the local rates, it hardly needs argument to convince us of their pernicious tendency in so far as they do not fall upon the value of land. The heaviest contributions to them come now from the prices of goods sold at retail and the rents paid for dwellings, and at least the second of these elements is in a high degree regressive as between grades of income and appallingly oppressive at each grade of income to the larger as compared with the smaller family. The taxation of dwellings is perhaps upon the whole the most evil tax in principle which has ever been invented; it attacks a necessary of life the demand for which is elastic. It is unpleasant to think that some five or ten per cent. of a minimal income may often be exacted by this device. As against this we have to weigh the considerations that rates are a method of raising local revenue and that some substantial part of their incidence rests in all probability upon beneficiaries of land value. On the first point we see no valid argument, granted that income taxation were suitably extended, against

utilising it for local as well as for central purposes. It would, of course, be necessary to develop specific doctrines of local attachment for individuals and of the proportions of their incomes properly liable to local income-taxation. To do this satisfactorily and with acceptance would certainly not be easy, but it is precisely my case here as elsewhere that the difficulties of rational taxation ought to be faced ; that we can no longer afford to turn our backs upon them and let things drift. It is vastly important to educate ourselves in economics and I can imagine few more fruitful methods than that of inducing serious popular discussion of the questions—who ought to contribute to local expenditure, for what reasons, and in what amounts ?

The land value and capital aspect of the matter is more difficult, and, since an analogous problem would present itself if taxation of commodities were abandoned, I must aim at some statement which will, in outline, cover both cases. One reason why many solid minds will refuse to recognise what seem to me the palpable wickedness and folly of these taxes is the enormous difficulty of devising a retreat from them which will not involve, in the short period at least, substantial windfall gains to certain individuals. Repeal of rates might in theory be accompanied by the introduction of a special tax on land values, which would absorb about as much land value income as the rates in fact intercept, but I confess to doubts of the practical wisdom of any such attempt. It is more difficult to conceive even in theory of any satisfactory way of preventing considerable benefit to owners of rated buildings if the rates were abolished, and to special industries and interests if commodity taxation were abandoned. Possibly in the case of the larger firms in the drink and tobacco industries some special taxation of surplus profit might be reasonable over a limited period. In the main, I admit to feeling on this side of the matter that a price has to be paid for escape from a faulty policy ; after all the price is for a limited period : the evils of the faulty policy, if it is persisted in, are permanent and cumulative.

It would be interesting to pursue in detail the minor absurdities of our stamp duties, the ineptitude of N.D.C., the inconsequence and monstrosities of our dealings with entertainments, petrol, and motor-transport, but my time and your patience are alike approaching exhaustion, and I shall prefer to attempt some rounding off of the main ideas which have underlain my paper. It will, I hope, have been evident that in suggesting abandonment of rates and indirect taxes and reliance upon a generalised system of progressive income taxation and taxes on inherited wealth, I have been actuated by political at least as much as by economic considerations and by a feeling for what I will venture to call civic virtue more than by anything else. I believe in direct taxation not merely because I see in it the only potentially equitable system and therefore (partly) the only truly productive system in the long run, but also because I see in it enormous possibilities of interesting the citizen in the State, in his relation to it, in what he gets out of it and what he gives to it. I confess to some impatience of the argument that indirect taxes should be credited with a merit in not being felt, holding strongly on the contrary that we ought to feel our taxes, that we are far more likely to value what we know we are paying for than what we suppose we are ' scrounging.' Is there not, in reality, a definite satisfaction in meeting one's bills which ought not to be denied to the citizen of a democratic state ? I want, in fact, to suggest

that whatever arguments of technical expedience or practical convenience may urge us to get the money in without worrying unduly about where it comes from, this is a kind of conduct which no wholesome person tolerates for a moment in his own case, and that the State in this as in other matters should set an example above rather than below the level of its average citizen. By clinging tenaciously to methods which may have been appropriate or inevitable in past centuries we are forfeiting the encouragement to and enlightenment of good citizenship which might be achieved if our financial principles were more clearly defined and more sanely defensible economically and morally than they actually are.

It is part of my thought on the matter, and I wish to make this clear, that our direct taxes need a good deal more refinement and elaboration to suit them to our needs. We must be prepared to go a good deal further in adapting them to differences of individual circumstance than we have in the past. In particular there is required, in my opinion, far more adjustment to the number of persons whom a given income in fact maintains, a far more liberal treatment of widows and invalids dependent upon small incomes from property, more consideration of the difference between the man who enjoys a large income for many years in succession and one who earns it only once or twice in a lifetime. Another large field for enquiry is offered by the problem of variable profit. As we abandoned the income tax after Waterloo, so we scrapped after the Great War the excess profits duty. Some attempt at further experiment in that field seems to have underlain the initial plan for N.D.C. Sooner or later, if private enterprise survives, there must be development on this side. There are again a number of obvious problems awaiting attention in the taxing of inheritance. None of all these urgent matters are likely to be seriously attended to unless we can break with that traditional attitude towards finance which I have ventured to depict and criticise, and partly for that reason I have restricted myself to generalities in presenting my case.

There remains for consideration one final legacy from the age of *laissez faire* : namely, the famous canon of exempting from taxation the minimum necessary to subsistence. I suspect that the ghost of this canon lurks somewhere behind our curious procedure in regard to the allowance on account of children. Possibly £10 was thirty years ago the officially accepted minimum of subsistence for an income-tax baby and for aught I know £60 may be to-day. ' Ghost,' advisedly, since there never has been a time at which taxation failed to nip at least nose and fingers of the ultra-poor. However this may be, it is very much in my mind first that this canon though logical enough under *laissez faire* has no claim to be accepted to-day ; and secondly that it is living on in our altered state and playing a part in that, to me, curious idea of many people that nothing appreciable is really due to the State until one has passed, say, the £3 a week line for an individual or the £300 a year line for a married couple with two children. My feeling is, on the contrary, that a contribution sufficiently heavy to be ' felt ' should be called for from the very bottom of the scale. In this matter I am wholly on the side of those German economists who insisted throughout the nineteenth century that something was due to the State from the very poorest, and I would suggest most seriously that the willingness to bear taxation cheerfully, which is evident in Germany, and which puts us here to shame, is a noteworthy

symptom of essential vigour and value in the life of a nation.[2] I have, then, no patience at all with the typical bourgeois socialist who considers that the modest £500 which represents to him a minimum standard of cultural existence ought to be sacred so long as any individual is allowed to spend up to £20,000 a year. I will go far with him in promoting such changes in our institutions as will make enormous incomes impossible. But I should feel more comfortable if I could persuade him, pending those changes, to accept my own thesis, that honour compels the citizen, even of a faulty community, to make a sensible sacrifice towards its upkeep. I use deliberately the word 'honour' rather than the word 'equity.' If it is a question of what is 'fair' it seems clear that the contribution made by our working and lower middle classes, both in their productive labour and in their expenditures on rearing children, so grossly exceeds what is due from them as compared with what is due from the wealthier classes as to justify a claim that incomes below £300 per annum should pay no taxes at all. But everyone who is worth anything knows in his bones that the attempt to base human association upon equity only is doomed to failure. If individual soldiers insisted to the limit that it was unfair for them to be killed, if women insisted that it was unfair for them to suffer and die in child-bed, if everyone everywhere stood strictly upon his rights, no one would get anything. We need to qualify, and we do in practice, all of us, qualify, the claim for our rights with the assertion of our honour, and I am convinced that it is psychologically essential, if we desire to build a democracy, to enshrine this principle in our financial institutions. Of all the ideas which we have inherited from *laissez faire* finance the most dangerous for us to continue (granted that we are abandoning *laissez faire*) are the notion of the exempted minimum, and the notion that indirect taxes are desirable because men do not feel that they are paying them. The State ought not to mean so little to anyone as that he will not assert his right to contribute towards it. Still less ought the State to descend to picking pockets. Granted, our State is so imperfect that some of our citizens cannot afford to contribute. We do not *in fact* exempt them : we pick their pockets by rates and indirect taxes. Surely it would be better to put the matter on an open footing, and where we felt shame or met obstruction in collecting from the very poor took measures to make them less poor and in the meantime returned to them in benefits something more than the value of the contributions they made.[3]

[2] Germany enjoys the advantage that her people has never been conquered : in England we still reel from 1066 and all that !

[3] If I am asked *what* benefit could be devised which would really cover all cases, I will answer : a lottery ticket. Not in the ordinary sense of a specific lottery where tickets are sold and the receipts distributed between prizes and tax, but by allocation of say £5,000,000 per annum out of general revenue in prizes and the issue to every man, woman and child in the country of a free ticket for the draw. After all, one of the prime advantages of civilised life is the chance which it gives to the individual of attaining wealth : that chance, however, as things are is appallingly weighted in favour of the middle and upper classes. To him that hath, there is given. Lotteries as a means of raising revenue seem to me only less dirty than taxes on drink or prostitution : they are just one more method of exploiting lightheartedness, extravagance, vice. But a lottery that would *distribute* revenue stands on a different footing. This would bring hope to millions and temptation to none.

SECTION F.—ECONOMICS

COMMUNICATIONS

Dr. M. Bowley.—Housing in Scotland.

The purpose of this paper is to analyse the main differences between Scottish and English housing problems in the post-war period. The housing situations in Scotland and England, respectively, before the Great War are examined briefly in order to bring out the essential features of the problem, and some attempt made to explain the greater seriousness of overcrowding in Scotland than in England. The effects of the cessation of building during the war on the situation in the two countries and the emergence of an artisan and middle-class housing problem are outlined. In the light of this data the achievements of the post-war housing policy are analysed to discover whether the Scottish situation requires treatment different from that of the English.

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Dr. Thomas Adams.—Some economic aspects of urban concentration.

Concentration of industry, economic activities and population in urban centres is essential to secure economic benefits to be derived from scientific progress and need not militate against social welfare. Concentration, however, has become excessive in many urban centres, and has caused intolerable congestion of traffic, impairment of industrial efficiency, and overcrowded building development. It is contended that :

(1) The most powerful force in causing urban concentration is the existence and potentialities for development of transport facilities allied with certain favourable qualities in the natural situation, and the planning and control of these facilities is most essential to prevent excess.

(2) The steady flow and free movement of street traffic is essential for economic efficiency and urban areas need to be planned or replanned to provide the space required.

(3) If the main transport facilities are properly planned and controlled there will be less need to attempt artificial restriction of the location and distribution of industry, and if ample space is provided for purposes of locomotion this space will suffice for essential purposes of air space and recreation.

Economic solutions resolve themselves largely into questions of transport and land prices. The reduction of costs of transport involves the elimination of unnecessary travel ; and the reduction of land prices the elimination of values based on improper or unhealthy uses of land.

More research is needed to ascertain the best methods of reducing ' friction of space ' between producers and consumers of goods and services, and between places of residence and places of work and recreation. Town planning needs to be based more on the data of the economist and less on consideration of sentimental values.

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Mr. A. J. Wensley.—Localisation and concentration of industry.

The general trend towards industrial concentration. The relative growth of the major industrial areas. The central industrial belt.

The industrial composition of the major industrial areas. The location and trend of individual industries. Changes in the location of individual industries and the rate of growth of industries which are relatively static in their location.

Recent developments in the Ministry of Labour Midlands Division. Relative rates of growth of the component areas and of individual industries.

The factors underlying the process of concentration. Cumulative tendencies. The probable future trend in location.

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Mr. A. Collier.—The social economy of crofting districts.

Introductory.—Difficulty of defining a 'crofter'; size of crofting population and districts in which they live; crofter's mode of life and sources of income; township the social unit, individual holdings and common grazing.

Origins of problem.—Break-up of clan system; growth of population consequent on introduction of potato, inoculation, cessation of private warfare, and the kelp boom during the Napoleonic Wars; the coming of sheep and the clearances created by 1820 acute over-population. Emigration, either individual or communal, was forced on the people, but it is remarkable how tenaciously they resisted.

Modern Period, 1875–1939.

1. Crofting, legislation. This gave security at the cost of perpetuating the 1886 situation.
2. Free trade. Cheap meal lessened the crofter's self-sufficiency and caused him to depend more on auxiliary employment for cash to pay for imports.
3. Education gave Highlanders closer contact with outside world and desire for better living conditions.
4. Failure of sources of additional income—fishing, local industries, etc., is only partly compensated for by road work, tourist trade, etc.
5. Social services have in post-war years given Highlanders a larger cash income.
6. Improvement of roads enabled vans to bring new cheap foods and has revolutionised diet and dress.

Changes more rapid than in almost any other region have been forced on a social economy ill-adapted to meet change. Distance yet loss of isolation and the destruction of the foundations of the old economy, coupled with reluctance to abandon the crofts, have given rise to the present problems.

Excursus.—The bases of the present prosperity of Orkney and the difficulty of producing similar results in other districts.

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Mr. A. D. K. Owen.—The finance of Scottish government.

The union of Scotland with England and Wales involved the co-ordination of two fiscal systems and the disappearance of the Scottish Treasury. The arrangements which were made in 1707 were, on the whole, very favourable to Scotland and they led to remarkably little friction between the two countries.

Broadly speaking, Scotland received more than she gave to the joint Exchequer in the eighteenth century, but this position was reversed in the nineteenth century as Scotland became highly industrialised.

In the present century the development of budgetary policy has favoured a Scotland suffering from industrial depression and rural depopulation. Official figures suggest that she now gets more than she gives, but these figures require some qualification.

An analysis of recent trends in public income and expenditure on Scottish account.

The development of the grant-in-aid for Scottish purposes. An analysis of the present position. The growing strain on the rating system.

The outlook for Scottish government finance.

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Mr. A. Cairncross and Mr. G. E. Tewson.—Finance of new enterprise in Scotland.

1. Why new enterprise is needed : long-run trend in the heavy industries unfavourable : lack of second line of defence.

2. Inadequacy of traditional methods of finance of new enterprise.
   (*a*) Growth and proliferation of firms through ploughing back of profits. Ineffective in a period of depression and re-localisation.
   (*b*) The Stock Exchange. The new issue market before and after the War. Relative importance of the Glasgow and London markets as sources of finance for Scottish industry.
   (*c*) Banks, Investment Trusts, Insurance Companies, and other intermediaries.

3. New methods of finance. Government assistance to new enterprise through provision of premises (Trading Estates), revenue (grants from Special Areas Commissioner), and capital (Special Areas Reconstruction Association). The Nuffield Trust and the Scottish Industrial Development Trust.

4. Some suggestions :
   (*a*) Extension of Special Areas. Need to take an industrial unit like the Clyde Valley for a comprehensive planning policy.
   (*b*) Prolongation and extension of the work of S.A.R.A.
   (*c*) Need for permanent Scottish Economic Committee providing information and statistical service.

* * *

Rt. Hon. Lord Nigel Douglas-Hamilton.—Some features of the Special Areas in Scotland.

The economic structure of the four Special Areas is very similar and the decline of their industrial activity can broadly be ascribed to the same causes. The social problems which arise therein may have their counterpart in all parts of the country, but still possess distinctive features. Readjustments of industry have been necessary in the past, but the consequences become more serious when carried out without design in a complex community.

The remedy which has been attempted has only been carried a short distance. Its object was to re-invigorate the public services and introduce the newer and expanding types of industry so as to provide opportunities for the inhabitants, at least equal to those elsewhere. Some consideration of the assistance to local authorities, such as baths, sewers, roads, parks, hospitals and clinics is necessary. Pure economic improvement is not easy to achieve. Comparison is made of the economic concessions received through Special Areas' legislation—loans, remission of rates and taxes and the establishment of factories for leasing.

Assessment of results is difficult owing to the great variety of factors, all of which have their influence on any community. The rearmament policy has played a big part, but so also has international uncertainty. The rating system in Scotland presents peculiar difficulties. The entire absence of economic forethought or, in many cases, even power to plan lines of development make the avoidance of chaotic building difficult : the necessity for some form of planning is re-emphasised and anticipation of demand for services.

The artificial limitation of the Areas has presented difficulties, which are the more acute now that the more marked urgency of the problem seems to have passed. Any real solution must be on a long term view, and on such a view the adaptability both of men and the area is important ; adaptability in its turn is dependent on the variety of enterprises which compose that industrial structure. Only when that

variety is established can the Special Areas' problem as such, or the danger of its reappearance be considered removed.

* * *

Discussion on The economics of socialism.

Prof. L. M. Fraser.—What is socialism ?

This paper is concerned with distinguishing and sorting out the various issues which go to make up the current controversies as to economic socialism. It is not concerned except accidentally with socialism as a political creed.

Six main strains can be distinguished in socialist economic doctrines. In three different ways socialism constitutes an attack on the principles underlying existing economic institutions :

(*a*) It opposes private property in the means of production ;
(*b*) it demands the substitution of public for private enterprise ; and
(*c*) it calls—or may call—for the substitution of central planning for the existing price system.

In addition, however, stress may be laid by socialists upon

(*d*) the improvement of the economic position of labour, with special reference to the elimination of the threat of unemployment ;
(*e*) the elimination of inequalities of incomes ; and
(*f*) the battle against monopolies and vested interests of all kinds, including such working-class monopolies as trade unions, etc.

These six strains having been distinguished and related to one another it becomes possible to formulate with reasonable clarity the distinction between socialism and (i) communism ; (ii) the trade union movement. Finally the question is asked whether ' national socialism ' is a contradiction in terms.

Prof. A. G. B. Fisher.—Socialism and material progress.

Socialism is primarily a doctrine concerned with means, implying the belief that a planned economy will work more efficiently than one based upon the free decision of individuals. Strictly speaking, the *end* of the plan is irrelevant. But as socialist thought has usually evolved under the stimulus of the failure of existing economies to achieve ends thought desirable by public opinion, socialists often implicitly believe that devotion to such ends—(*a*) higher incomes and (*b*) more stable incomes and employment—is also part of socialist doctrine. The possibility of a clash between them is overlooked, or it is assumed that any policy calculated to achieve the latter will also, as a by-product, achieve the former too. The gravest defect of capitalist economies in practice is their tendency to sacrifice material progress for stability, interpreted as the maintenance of the existing income pyramid, but current socialist doctrine is also liable, in its eagerness to achieve stability directly, to sacrifice material progress. The most pressing practical modern economic problem is the devising of methods to facilitate and accelerate the transfers of productive resources without which material progress is almost impossible, and practical socialist programmes must be tested by their appreciation of this point. It is probable that if measures for raising the level of income are tackled first, the same measures will also be found to be the most effective permanent solvent of unemployment problems, and will at the same time necessitate that reconstruction of the income pyramid which most socialists also approve.

Mr. R. L. Hall.—Some problems in international economics for socialists.

It is not more difficult to construct a theoretical economic system for a Socialist *state* than for other states, since the fundamental problem of scarcity is the same, and the hypothesis that susbstantial equality of income is to be sought introduces

no special difficulty. But the simplicity of treatment exists only for the closed economy under unified control : unless national states which become socialist are willing to merge themselves in a single unit, they must face problems connected with the exchange of goods and the movement of resources. And it is doubtful whether the peoples of wealthy states will agree to complete unification, since the free movement of labour which this implies must lower their standards of living.

Prof. Robbins has suggested that international economic relations between planned economies are likely to be uneconomical, unstable, and productive of friction. These conclusions do not appear to be either necessary or probable for socialist states which do not pursue predatory policies. In these conditions, arrangements resembling those which would be reached with international freedom of trade are quite simple to operate, and offer advantages which should make them acceptable to all national groups. The difficulties connected with the movement of resources are serious, but do not seem insuperable in the case of knowledge and of capital, since there is more resistance to a reduction in the standard of living than to a slowing in a rate of advance. In some cases movements of population may be possible, but these are less likely.

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Mr. A. Beacham.—The Coal Mines Act, 1938, and the future of compulsory amalgamation in the coal industry.

Legislative background provided by Mining Industry Act, 1926 (Part I) ; Coal Mines Act, 1930 (Part II) ; and Coal Mines Act, 1938 (Part II). The latter replaced the Re-organisation Commission (established 1930) by the Coal Commission.

The Re-organisation Commission failed. Chief causes were : (i) Valuation difficulties, especially where amalgamation projected between relatively prosperous and poor concerns. (ii) ' Wrecking Clause ' (1930 Act) laid down very onerous criteria with which schemes had to comply upon penalty of non-ratification. Result was that Commission's advocacy of complete mergers which accentuated these difficulties became less pronounced. Failure to secure ratification of West Yorkshire partial amalgamation scheme brought Commission's activities to an end. The 1938 Act repealed the ' Wrecking Clause ' and reduced power of Court to that of modifying schemes in this respect. The unenforceability of partial amalgamation schemes was upheld. Operation of Act deferred until 1940 with possibility of further delay.

Re-organisation a series of compromises between individual interests and wider interests of industry and society. The latest compromise more satisfactory in certain respects but tending further than its predecessors towards autocratic planning from above. Some doubts also may be expressed concerning the Court's interpretation and application of re-organisation legislation. Finally we may note the influence of coal-owners on legislation and its implications for producer control.

* * *

Mr. J. C. Gilbert.—Investment Trusts in Dundee.

The early history of the Fleming Trusts and of the land mortgage companies in Dundee provides an example of the twofold origin of British investment trusts. The history of these two groups of Dundee companies goes back to 1873. The Fleming Trusts were unregistered common-law trusts until 1879, when they were registered as the First, Second and Third Scottish American Trust Companies. No debenture debt was incurred until 1910 and the range of investments was mainly restricted to bonds of railroads in the United States until that year. In 1896 a sister company, the Northern American Trust Company, was formed. This company had wide investment powers and issued debenture stock. The land

mortgage companies issued terminable debentures and invested mainly in mortgage loans in North America. In 1889, as the result of a process of amalgamation, the Alliance Trust, which is now the largest investment trust in Europe, was formed. The Dundee companies pursued a conservative dividend policy and built up large reserve funds. During the post-War period the land mortgage business has been eliminated as far as possible and all the Dundee companies are now general investment trusts. There has been a large expansion in the capital and debenture debt of the companies and a large amount of the short-term debt has been funded.

* * *

Mr. J. H. Wilson.—Exports and imports in the trade cycle.

In a paper read before Section F of the British Association in 1938, Sir William Beveridge drew attention to two newly observed facts concerning British industrial fluctuations: first, the leadership of industries producing for, or dependent on, the export trade into and out of depression; secondly, the apparent tendency of the British trade cycle, as represented by the general unemployment rate, to turn up or down at a particular time of year, viz. the months July–January.

The present paper represents an examination of the hypothesis put forward on the basis of these two facts, namely, that the decline in the export trades which seems to initiate a depression is a result of fluctuations in agricultural purchasing power. Pre-War and post-War figures have been examined and it has been found that the evident decline in monetary purchasing power is caused by a decline in the *price-level* of imported agricultural goods, their *physical volume* remaining steady. On the other hand the *price-level* of British exports—largely manufactures—remains very steady, actually rising in the first few months of depression. In consequence, the *physical volume* of British exports declines sharply and precipitates a general trade slump.

The second part of the inquiry is devoted to a consideration of the causes of the fluctuations in agricultural prices, and it is suggested that these are the tendency to over-production at times of high price combined with the short-period inelasticity of supply, and powerfully enhanced by speculative dealing. The over-production itself, the evidence would suggest, is due not to physical causes affecting the yield per acre, but to an increase in the acreage planted.

THE ASSESSMENT OF PHYSICAL FITNESS

ADDRESS TO SECTION I.—PHYSIOLOGY

By Prof. DAVID BURNS, M.A., D.Sc.,

PRESIDENT OF THE SECTION.

Introduction—Where we stand—Comparative Death-rates as a Measure of Physical Fitness—Infant Mortality and Rate of Breeding—Differential Birth-rates—Health and Unemployment—Health of the Young Worker—The Problem stated—What is Physical Fitness?—Types of Testing—Training and Fitness—General Physical Training—Nature of Tests—Indices of Fitness—Limiting Factor in Efficiency—Muscle Tone—Measures of Fitness—Value of 'Stunt' Tests—Exercise and Fitness.

'No mariner ever enters on a more uncharted sea than does the average human being born in the Twentieth Century. Our ancestors thought they knew their way from birth through all eternity. We are puzzled about the day after to-morrow. . . . Never before have we had to rely so completely on ourselves

. . . ordinary men set to deal with problems of heart-breaking complexity. All weaknesses come to the surface.' (Lippmann.)

One of these complex problems involves the whole future of civilised man. The risks and hardships, which in the past ensured that only the fit survived, have been charmed away by the advance of civilisation. No longer are we moulded by our environment. We mould our environment to suit our bodily needs. As a result, instead of the weakest going to the wall, we build a protective wall round them from the cradle to the grave and only permit the more hardy to experience the buffets of a rough-and-ready world. Even they are guarded against many natural risks. The cost of all this protection is enormous. Some ten million pounds per year are paid for doctors and drugs under the Health Insurance Act, and this is small compared with the total expenditure on National Health, Factory Acts, etc. Are we getting value for our money? Is the nation fitter for life since the introduction of the first Public Health Act in 1848?

Are we going the right way to ensure the optimum fitness of the maximum number, or are we merely attempting superficial repair instead of a thorough reconditioning? Is our race degenerating or gradually becoming one of supermen? McDougall (1921) is doubtful. 'Will the human qualities which have carried our civilisation upward to its present point of complexity—will they suffice to carry it further, or even to maintain it at its present level? That is a grave question. But a still graver question calls for our most earnest consideration, namely: does not progressive civilisation—while it makes ever greater demands on the qualities of its bearers—does it not tend to impair, has it not always in the past actually impaired, the qualities of the peoples on whom it makes these increasing demands?'

This is the cry of despondency—of one who allows civilisation to get on top of him instead of using the available scientific powers to control civilisation. Carrel, too, joins the detractors of progress. 'Every living thing depends intimately on its surroundings and adapts itself to any modification of these surroundings by an appropriate change.' He goes on to ask how we have become adapted to modern conditions. Have we benefited? 'It is less fatiguing to work in a factory or office than on the farm. Natural bodily exercises have given way to well-regulated sports—in sheltered arenas. In this way we can develop muscles without being subjected to the fatigue and hardships involved in the exercises pertaining to a more primitive form of life.' He has a somewhat sadistic craving for fatigue, hardships and inclemencies of the weather, and wails that we are growing soft, lack audacity, and don't worry enough.

Can we place any cogent arguments against this distinguished psychologist and eminent biologist and in favour of the ascent of man?

Comparative Death-rates as a Means of Assessing Fitness.

Death-rates interpreted under stringent conditions may be a useful index of the physical fitness of a community. Until the first census in 1801, no accurate general record of mortality was kept. Information was available in London and other large towns in the form of Bills of Mortality published at regular intervals and designed to give information on the number of deaths from plague. Because of the haphazard method of collecting these figures

from the returns of the Company of Parish Clerks, no reliable conclusions can be drawn from them. In 1838 the General Registry Office came into being and, moulded by the statistical genius of Dr. Wm. Farr, as medical adviser, it has regularly supplied accurate figures and periodically issued reports on the state of the population based on statistically valid findings. These reports and supplements are a rich mine of information apparently neglected by the more vocal of our publicists. From such reports and other similar statistical matter (*Year Book* of the League of Nations Economic Intelligence Service) we may learn that the crude death-rate at all ages and in all countries has steadily decreased, e.g. in England and Wales from 21·4 per 1000 (1871–80) to 12·1 (1921–38). In the same period the average infant mortality has fallen from 146 to 59 per 1000 births—a steady saving of infant life which seems likely to continue.

Closer study of these reports shows that certain counties, called by the Registrar-General 'remainder of S.E. England' (Bedford, Berks, Bucks, Essex, Herts, Kent, Middlesex, Oxford, Southampton, Surrey, Sussex and Isle of Wight but exclusive of Greater London), have a lower death-rate at every age under 60 than in the rest of England and Wales. Certain areas, e.g. South Wales, Northumberland and Durham, on the other hand have higher death-rates.

Death-rate in each Age Group.

	0–14.	15–34.	35–54.	Over 55 years.
S.E. England . . .	4·8	2·2	5·7	40·5
Northd. and Durham . .	7·7	3·2	7·5	47·0

Infant Mortality and Rate of Breeding.—That such a difference can occur calls for investigation, especially on the infant mortality rate where the divergence is widest—e.g. Oxford has an infant death-rate of 38, to contrast with 78 in Durham (1934). Even higher infant mortality rates are found in county boroughs. If we are to reduce our general death-rate to 8 per 1000, which Sir B. W. Richardson (1875) claimed should not be exceeded in any district and which is closely approached by New Zealand with 8·5 and Holland with 9·2, we must concentrate on reducing the toll of infant lives as Oxford and these two countries have. We have passed the age when death in infancy was regarded as quite a common thing needing no comment.

'Mamma, I saw a baby dead,
Within a narrow coffin laid.
Its eyes were shut, and cold its cheek :
I call'd it, but it could not speak.
And must I die? my dear Mamma,
I really hope not, I am sure ;
I thought the doctor life could save
And keep us from the dark cold grave.
. . . . .
So certain as we draw our breath,
So certain we are claimed by death.'

(From *Pretty Little Poems for Pretty Little People, Explanatory of the Operations of Nature, in a Style suited to their Capacities, from the age of Two to Twelve Years*, by Louisa Watts.)

A recent analysis (C. M. Burns, 1939) of the figures for County Durham shows quite clearly that those families who breed at the modal rate and who do not have more than three children have an exceedingly low death-rate irrespective of social class. The modal rate is found among those who have their first child when the mother is between 20 and 25 years old and the next two children spaced not less than two years apart. Since, however, the race cannot be maintained unless the average family contains three children, there must be some families with more than three. It has been shown that, if breeding is carried out at such a rate as to give the best biological conditions, i.e. the fourth child round about a maternal age of 30 and the fifth and sixth child between the maternal ages of 30 and 35, then fourth, fifth, and sixth children may have an expectation of life not significantly worse than in the best families of that size, almost irrespective of economic status.

Breeding at a rate greater than modal or pregnancies outside the modal age limits, i.e. first before age 20 or after 25, increases the maternal and infant death-rates. The rate, lower than in the country as a whole, is higher than it need be in the ' best ' counties and among the more comfortably situated parents because of the tendency of such people to postpone marriage, and thus the possibilities of pregnancy, to an age beyond the modal. In the professional classes, for instance, 36 per cent. of the women who married, did so after they had passed 30. On the other hand, industrial areas have an enhanced figure because many conceptions take place when the mother is too young, and the rate of reproduction is too rapid to permit adequate physiological and/or economic reconditioning.

We are behind three predominantly agricultural countries (New Zealand, Holland and Denmark) in preserving potential citizens. While a man aged 60 is not less unproductive as a worker than a child under 14, the potentialities of the latter are lacking in the former. These three countries (Denmark achieves its inclusion by eliminating the weaklings under one year) have a much lower death-rate during the productive ages, and potentially productive ages, than we have, principally because they have no large industrial towns scattered thickly over their land and hence death and disablement from ' crowd ' diseases is low. Our own farming community compares favourably with New Zealand.

Differential Birth-rates.—Our birth-rate, in common with that of all civilised countries, is declining. The present level of births and infant deaths is largely maintained by those people, about 10 per cent. of the population, least fitted physically, mentally and economically to form the basis for almost 35 per cent. of the next generation. According to Titmuss, ' Our numbers are being increasingly and disproportionately recruited from amongst the unemployed, the unhealthy and malnourished, the mentally sub-normal and from the ranks of those reared in the most unsatisfactory environment and subjected to social and economic hardships.' J. B. S. Haldane says, ' If the existing differences in fertility of the social classes continue we may expect a slow decline of perhaps one or two per cent. per generation in the mean intelligence quotient of the country.' This should give food for thought, as 50 per cent. of our present population have an I.Q. of 85–115, 25 per cent. are below 85, 4 per cent. below 70, and only some 25 per cent. above 115. (Cattell, 1937.)

The men in the only areas where the average reproduction rate is adequate

to maintain the population are not on the whole as fit as in the ' rest of S.E. England.' This is indicated by the excessive rejections of recruits to the Army from these areas, and from figures given by the Ministry of Labour to show the physical health of the unemployed on the Register in October 1934. Over half of the applicants for admission to the Army in 1936 in the Northumbrian region were rejected, or, put in another way, the excess of rejections in this area was 60 per cent. greater than those of the Home Counties. Fisher and Fiske, as the result of an examination of over 10,000 persons seeking ' relief,' state that none were of good physique ; some 10 per cent. of the males and 23 per cent. of the women were ' fair,' the others required medical treatment, 10 per cent. somewhat extensive treatment, and 5 per cent. were classed as very bad.

Health and Unemployment.

Men handicapped by a poor physical start in life are still further dragged down by the difficulty of getting and keeping employment. The last to be engaged and the first to go are the unfit. Cause and effect here stretch into the future. Poor health standards and employment handicaps among the marginal families of the community will breed a new generation of C3 citizens unless counteracting factors are put into operation. As a result of the drastic cutting down of staffs during the depression in the U.S.A., men and women who had a history of ill-health formed a large proportion of those without employment—one in every twenty heads of families seeking State relief was unable to work because of chronic disability. (Marsh, Fleming and Blackler, 1938.)

This raises the difficult subject of the extent of morbidity as apart from mortality. The more common causes of premature death are not the most frequent causes of illness. Accurate information on morbidity is hard to get. Figures from insurance companies apply generally to people comfortably off—in general, tax-payers. Sydenstricker and his colleagues made an extensive study of the prevalence of sickness among families (classified by economic status) in Hagerstown, Maryland—a town of 30,000 inhabitants. They found that chronic illness was under 2 per cent. among the comfortable as against over 11 per cent. of the reported illnesses among the poorer heads of families. The study of records of absences due to sickness indicated that, on an average working day, 2 per cent. of the workers were disabled by illness. Male workers lost on the average from 7 to 9 days a year from illness, females from 8 to 12 days.

Health of the Young Worker.—So much for the adult worker of the marginal classes. What of the young worker ? In the Annual Report of the Insurance Section of the National Union of Distributive and Allied Workers (February 1939) it is stated that the younger section of their membership was at present exceeding the provision made for them in the valuation basis of the scheme. By the end of 1938, of those who had entered the scheme in 1936 (at 16 years), more than 50 per cent. had tendered certificates of incapacity for work. Over 13 per cent. had been incapable twice, 5 per cent. three times, and 3 per cent. four or more times during the period. Approximately only 5 per cent. of these juveniles had been reported ill during the five years preceding their

entry into membership. The conclusion drawn is that these young people have not the reserves of health necessary for an industrial life. The report concludes: ' It must be remembered that the year selected (1936) covers the 1920 births (the highest post-war birth rate) and that may have some bearing on the problem.'

The Problem.

Not only must birth-rates, death-rates and the toll of those who are clinging to a precarious existence, dogged by ill-health and poverty, be considered in any attempt to assess the fitness of the community, but regard must be given to the age distribution of the population. The death-rate for those whose working days are over has fallen to a very low level and cannot fall much further. This means that, combined with the low birth-rate, the increased longevity of the race will produce a greater proportion of people of high ages. Brownlee (1922) estimates that to get a crude death-rate of 8, some people must live to 125. Be that as it may, we have at present an annual bill for old age pensions of about forty million pounds, and Mr. Duncan Sandys, M.P., told the Conservative Party Conference in September 1937 that in thirty years' time it might easily be sixty-five millions on the present basis of grant. The estimated number of persons in Great Britain of 65 years of age and over would be 4·5 million in 1946 and 5·25 million in 1966. In fact, according to one of themselves, ' We old-age pensioners are now numerous enough to be a political force, and at the next election should refuse to vote for any candidate not in favour of increased pensions ' (W. Couchman). Enid Charles (1938) calculates that while some 12 per cent. of the population of England and Wales in 1935 were over 60 years of age, the figure in 1965 will be about 20 per cent. (*see* Appendix, p. 418).

The children (under 14) and the aged (over 60) will by 1960 form at least 38 per cent. of our nation. With a sex ratio of 0·9, about 30 to 35 per cent. of the population will have to support the remaining 65 to 70 per cent. Direct tax-payers in 1935 numbered about 2½ million and, as it is that class which has the lowest birth-rate and the best expectation of life, we may expect that in 1965 some 1½ million people will have to bear much of the burden of providing not only for their own old age and for the upbringing of their children, but for a steadily increasing number of superannuated and a larger proportion of the children of the poor unless heavier demands are to be made on the indirect tax-payers whose contributions to the State are already a serious burden on rich and poor alike.

' The child of to-day may have to face in his later life and his old age, economic difficulties beside which the lot of the present generation may seem to him, in retrospect, a happy one ' (Lowndes, 1937). Unless the proportion of fit people in the next generation is markedly increased over that of the present population, the economic problem will be insoluble. Hence the discussions of ' experts,' the ' movements ' of uplift groups, the wails of the amateur demographers and the nuncupations of politicians, all of which seem to result, as far as the man in the street is concerned, in a crop of new slogans: ' Drink more milk,' ' Bread for energy,' ' Eat more fruit,' ' Join the keep fit class,' etc., etc. Official posters appear on the hoardings exhorting the populace to do

this or avoid that, all in the name of national fitness. Enormous amounts of money are spent on publicity and, as Carrel says, ' As a result large quantities of alimentary and pharmaceutical products . . . have become a necessity for civilised man.' The aid of Science is invoked, but her advice is generally unheeded in the hasty search for a panacea—an easy way to gain or maintain fitness. The League of Nations (Health Section) appointed a group of experts to formulate the physiological bases of rational physical education and to determine which somatometric measurements and functional tests should be universally recommended as descriptive of physical fitness and form (1938). These international experts state that ' the aim of physical education should be . . . to benefit the whole community . . . and to bring about a sense of well-being.' ' So far, little is available which can furnish objective measures of the physical fitness of the population.' (Stouman and Falk, *Bulletin*, Health Organ., L. of N., 1936.)

What is Physical Fitness?

The phrase, physical fitness, if I may parody Linklater, is a good phrase. ' We are satisfied with it all unsupported, because it has acquired a numinous quality.' It is one of those magical phrases ' which mean so much to us that, when they are spoken with a proper solemnity, they induce in all who hear them a willing suspension of the critical faculty.' It is a phrase of many meanings. According to some, it denotes fitness for some form of athletics, others define it in terms of industrial output ; others again look only for potential soldiers. Cathcart gives the phrase a wider connotation and speaks of healthy bodies ' well balanced physically, mentally and emotionally, who will be capable of all necessary adjustments to their immediate environment be it work or play.' The fit person will have ' a harmony of motion, a grace of carriage, a pride of body, a mental concentration and quickness of reaction and the happiness and contentment which characterise the really fit ' (1938).

The implications of this summary of the qualities of the fit, involving as it does the bodily frame suitably bound together and moved by muscles controlled by an educated brain and an understanding soul—a definition which includes the whole man, an entity of extreme complexity which acts on and is acted upon by the outer world, animate and inanimate—apparently render the task of assessing fitness well-nigh impossible. One might say with Eliot—

> ' There is no avoiding these things,
> And we know nothing of exorcism,
> And whether in Argos or England
> There are certain inflexible laws
> Unalterable, in the nature of music.
> There is nothing at all to be done about it ;
> There is nothing to do about anything.
> And now it is nearly time for the News,
> We must listen to the Weather Report
> And the international catastrophes.'

Types of Testing.

In other and less exalted words, while accepting Cathcart's definition as ideal let us see how far, using the ordinary routine methods employed by physical trainers and others, we may assess individual physical fitness. Testing may be subjective or objective. In the former, a qualified panel of judges evaluate performance according to some 'sealed specification' in their own minds. This leads to trouble, for it means that they view phenomena through glasses coloured by personal beliefs. There is always a temptation, even in the most rigid thinkers, 'to build up theories and afterwards turn them into articles of faith' (Carrel). When the whole panel holds similar views, its judgment assumes an authority not easily challenged. The judge who dares to disagree with the majority of his fellows is classed as cranky or worse. Further, as Lindhard points out, judgment is apt to be swayed by the principles of conventional art or by current military beliefs on carriage. Objective testing is comparatively easy when one knows what is being measured—that is, a suitable norm or standard is selected with which to compare the unknown. What is an acceptable standard of fitness? A second is always a second, a yard a yard, and a pound a pound, but these units are measured against an arbitrary standard. Attempts to standardise human activities would be disastrous and would remove all interest from life. Even when the type of fitness is specified, human function is so variable, and the same individual may differ so much in his performance from day to day, that it may have no mathematical correlation. Of course, over long periods or in large groups of similar subjects, e.g. sprinters or weight lifters perfectly trained, variability tends to balance out. If the group is sufficiently large, the nature of the test carefully chosen and meticulously carried out, a coefficient of correlation of 0·9 may be obtained. No coefficient under 0·8 in such tests is acceptable.

Training and Fitness.—There can be no doubt of the validity of objective tests when they are applied to measure specific fitnesses. That is, a person may be assessed as fit for a particular performance involving a particular skill under specified conditions; but that is no measure of his general fitness to perform other actions for which he is not trained. 'The first characteristic of the trained man is the greater power to do work for which he is trained' (Zoethout). He works economically, i.e. at a lower calorie cost than the untrained, largely by cutting out unnecessary motions. He carries less fat load in muscle and in the body as a whole, and the concomitant adaptations of the circulatory and respiratory mechanisms are better correlated. He also establishes anti-fatigue habits both of body and of mind. But he has not necessarily an educated body. His apparent excellence may be due to 'cramming' on the part of an instructor, or even to self-cramming. Just as the 'brilliant' scholar of the cram school invariably fails to implement his promise when left to carve his own career at the University, so the 'trained' man is no whit superior to the untrained in carrying out new endeavours. This is clear from the following table (Table I), where the return of the pulse rate after 6 minutes to a figure near the pre-exercise rate is taken as a measure of fitness. Training, then, may be considered as a process of fitting the subject for a particular type of performance. If a country were prepared to entrust all its activities to specialists—one man, one job—and absolutely prohibit

TABLE I.

Subject trained for	Pulse.			Time for race.
	Before.	Immediately after.	6 mins. after.	
Test = 100-yard sprint.				
100 yards .	84	116	96	12 secs.
,, ,, .	82	146	92	12·1 ,,
,, ,, .	88	148	94	11·6 ,,
Average .	84·7	137	94	11·9 secs.
½ mile . .	78	146	104	12·25 secs.
Football . .	82	126	94	12·2 ,,
,, . .	84	164	108	12·1 ,,
Swimming .	88	152	110	11·3 ,,
Weight lifting .	74	140	102	12·4 ,,
Average .	81	145	103	12·05 secs.
Test = ½-mile race.				
½ mile . .	70	176	116	2·2 mins.
,, . .	78	152	84	2·27 ,,
100 yards .	84	176	100	2·56 ,,
,, ,, .	82	160	96	2·31 ,,
Out of training	88	148	106	2·48 ,,
,, ,,	96	172	116	2·45 ,,

(Data from Lipovetz, 1938.)

anyone from having a say outside his own job—i.e. a real technocracy—things would be well done and the task of assessing fitness an easy one. In such a state there would, of course, be no room for the intelligentsia, the publicists or the amateur politician. Thought and public spirit would be at a discount, but the machine would work efficiently.

General Physical Training.—What, then, of the so-called general training of the 'keep fit type'? Does this form of exercise keep hand and eye, muscle and brain in trim, ready for anything? Physical training of this type has been common on the Continent for many years and has probably been practised more extensively in Germany, especially in Hitler's time, than in any other country. The 'Hitler-Jugend' is a movement designed to keep young Germany physically fit for its future duties to the state. To quote from the official manual of training, 'Physical efficiency is not only the preliminary condition of your being passed as fit for military service later on, it is also a fundamental demand of the National Socialist view of life. We see in a systematically built up course of physical training an indispensable means of self-instruction in comradeship and in the team spirit. The Führer asks you

to develop your bodily talents and capacities to the utmost ; he wants a Youth Movement in which every individual member unites in himself the God-given Trinity of Body, Mind and Soul. Accordingly, the best German youth is not the wisest or the strongest but rather he whose training befits him to serve his Nation in whatever situation he may find himself.' There is no doubt whatever that the Hitler-Jugend, like our own Boy Scout Movement which it superficially resembles, has caught the imagination of German Youth and it undoubtedly gives a smart appearance to its members, but, either because it is taken too seriously or because of some lack of nutrition, endurance fails. Boys who seem physically alert in October look exhausted in December. The lesson to be drawn is that physical training *per se* had been overdone, and that the responsibility of the future of the Fatherland, and consequently of civilisation itself, lies heavily on bodies, minds and souls too immature to bear the strain. Recent athletic events where German school-boys—the picture of health, beautifully poised and symmetrically developed—were pitted against lean almost ungainly British boys, showed the complete superiority of the latter. Generations of body culture have not apparently reduced the percentage of rejections as unfit for the German Army.

Nature of Tests.

Tests which have been used to assess fitness fall into three classes :

1. Somatometric.
2. Physiological.
3. Psychological.

1. *Somatometric.*

The search for a relationship between the configuration of the body and physical fitness has been pursued since the time of Hippocrates. Such a relationship is elusive, and because of the complexity of body build and the scarcity of strictly comparable measurements, most of the findings lack validity.

It was natural, at first, to consider stature as an index of robustness. The tall man with a long reach was better able to hold his own in hand-to-hand fighting. Even to-day, height is taken into account in selecting recruits for the services and the police. The tall applicant, too, has generally a better chance of getting engaged in commerce and industry than his shorter competitor. Length, especially length of leg, is not merely an indication of genetic constitution but of a late incidence of maturity. Chest girth in relation to size of body, at first sight, appears to have at least a probable relationship to fitness, but Gould (1864), who carried out a thorough statistical survey of the manhood of the American nation during the progress of the Civil War, had grave doubts as to the validity of chest measurements for this purpose. Hutchinson showed clearly that the circumference of the chest is no measure of vital capacity, endurance or even of muscular strength, nor is there any evidence that it bears any relationship to the state of general health.

Criteria of Fitness.—Since the introduction by McLaren of systematic somatometric measurements as part of the routine of physical education there has arisen a host of indices of which perhaps the best known are Von Pirquet's Pelidisi and Franzen's A.C.H. indices. Tait McKenzie (1904)

advocated the use of the thoracic index—the relationship of the diameters of the chest to each other (introduced into anthropometry by Fourmentier (1874) at the instance of Broca). This index, except in the case of abdominal breathers, does give some measure of fitness, in that boys known to be less robust than their fellows have a lower index, 72–73 instead of 74–75 at age 16. It is also well established that suitable physical exercises can improve the index (Mumford, 1927).

Bayer (1939) classifies adult women according to the ratio between two indices. One of these, Si/S, is the ratio of sitting height to height, and the other, Bc/BA, the ratio of bicristal to biacromial width.

In general, chests may be divided into three types: the wine-glass—wide shoulders and narrow hips; the test-tube—both measurements small; and the barrel with broad shoulders and wide hips. Persons of the test-tube type are often abdominal breathers, i.e. they obtain their tidal air by contracting the diaphragm and displacing the viscera into a relaxed abdominal wall. Experiment shows that they have a larger effective vital capacity than the others and are generally more amenable to training. On the other hand, all three types are normal and are equally fitted, as far as bodily relations go, for the battle of life. One cannot mark down any type as fundamentally healthier than the others. The test-tube type is more prone to tuberculosis but less prone to rheumatism, diabetes and arterio-sclerosis than the barrel (Kretschemer, 1925).

None of these indices is valid as a measure of fitness, even when due allowance is made for race, type of body build, sex or occupation.

2. *Physiological Tests.*

Fitness is functional. The body must be tested at work. The measurement of vital capacity is generally classed as physiological although it is not strictly functional. This measurement, a common routine practice, has no real significance. The amount of air that a person can contain in his lungs is a measure of chest capacity and of the tone of the respiratory musculature, but the person with an extra large vital capacity has no advantage over one who has quite a small capacity provided that he has sufficient.

There is a prevalent error that so-called deep-breathing exercises where the shoulders are forced back and the chest brought forwards and upwards increase vital capacity. Actually, by fixing the pectoral muscles and stretching the abdominal wall, these procedures prevent full inspiration and expiration and increase the volume of air left in the lungs (residual air). Chest breathers have about the same V.C., whether taken at ease or on the stretch, while 'deep breathing' may reduce the V.C. of abdominal breathers by about 30 per cent. The value of deep-breathing exercise lies in its effect on the filling of the heart and so on the maintenance of cardiac efficiency.

One is on surer ground when using the various breath-holding tests either *per se* or against pressure. The former is a measure of the alkali reserve of the blood and of the determination of the subject not to give in. The 40-mm. test brings out both these qualities and, in addition, is a severe test of muscular strength and control.

Bainbridge (1931) and Dawson (1935) quote the results of experiments which show clearly that fit and/or skilled men carry out physical work with but

a slight increase in lactic acid, while the unfit, under the same conditions, have a higher blood-lactic acid content. That is, the reserve of alkali in the blood of the fit is large enough to cope with all or most of the acid released as a result of muscular exercise. Recruits have on the average 5 per cent. less available base than the soldiers. The range of alkali reserve of fourteen members of a Physical Education Department was 65–78 vols. per cent., as against 55–71 for twenty-two members of a Medical School (including some ambulant patients). Dawson states that three months' systematic physical education can raise the amount of available base by about 10 per cent. As a matter of interest, about 50 per cent. of trained athletes exhibit mild alkalosis and may give Chvostek's sign of incipient tetany. (Table II.)

TABLE II.

Subject.	*p*H of venous blood.	
	At rest.	During work.
Very fit . . .	7·42	7·40
Fit . . .	7·44	7·38
Less fit . . .	7·45	7·36
Not fit . . .	7·42	7·27

(Bock *et al.*)

Similar 'fitnesses' associated with other groups of muscles can be tested by various dynamometers. Martin (1918) introduced a new procedure into this type of test. Instead of measuring the strength of a subject's active pull on a dynamometer, he applied the pulling force to groups of muscles and recorded the force necessary to break down the subject's active resistance to the movement of the muscle-group under test. The summation of a series of selected groups of muscles thus gives an indication of the total muscular strength of that individual as well as of his determination to resist. It gives no measure of his skill or of his economy of movement. It may be asked, is muscular strength plus determination an adequate measure of general fitness?

Limiting Factor of Efficiency.—It is well known that the limiting factor, the factor which determines whether muscular strength can be exerted to its full extent, the factor which overrides the will to do, is vaso-cardiac efficiency. Goodall (1916) recognised this when he published his efficiency tests. If, after a measured amount of exercise, the pulse rate and blood pressure come back to normal in a specified time, depending on the severity of the exertion, then the subject of the test is fit. This stressing of the time for restoration to resting level is one of the fundamental facts taught by Sir James Mackenzie. The time occupied by the discharge of energy is almost constant, the time occupied by renewal is variable, depending on the efficiency or otherwise of the functioning of living cells.

With a healthy heart, cardiac efficiency ultimately depends on the venous

filling. A pump without a well may be a thing of beauty, the last word in mechanical efficiency, but its usefulness is non-existent. About 85 per cent. of the total volume of the blood is in the capillaries and veins under normal conditions. Under these conditions, all capillaries are not patent at any one time. The splanchnic viscera, and particularly the liver and the spleen with their rich venous supply, are capable of retaining much larger quantities of blood than they do. If, for any reason, more capillaries open up at the same time and the splanchnic reservoir becomes filled with blood, the amount freely circulating, the amount necessary to fill the receiving chambers of the heart becomes inadequate. (Table III.)

TABLE III.—*Approximate Distribution of Blood in Man at Rest.*

	In ml.		
Systemic circulation	2,310		Plesch.
Pulmonary circulation	2,190		Plesch.
Total volume		4,500	
Residual blood in heart	150		Dawson.
Arteries	450		Plesch.
Veins and sinuses	1,400		Plesch.
Capillaries	2,500		
Total volume		4,500	
Skeletal muscle	1,350		Spehl.
Lungs	1,000		Stewart.
Liver	1,000(?)		Barcroft.
Skin	500		Barcroft.
Spleen	300		Hartwig.

Muscle Tone.—The controlling factor in the distribution of blood, in maintaining an effective circulation, lies mainly in the tone of muscle—cardiac, visceral and, last but by no means least, ordinary skeletal muscle. If a trochar attached to a manometer is placed in the right atrium of a deeply narcotised animal whose pulmonary artery is clamped, a pressure of 100–120 mm. of water is recorded, and if the blood is allowed to escape, a half or more of all the blood in the body gushes out (Riml, 1929). 'Where does this blood come from and what is the force that drives it through the veins towards the heart? Obviously it comes from the reservoirs of blood in the tissues. Obviously also the heart is not involved; for its force is abolished by the clamp on the pulmonary artery. The pressure is produced within the tissues, and is due to their tonus; for it disappears along with their tonus a few minutes after death. Muscle tonus is therefore the force that produces this pressure and with it the flow of the blood through the veins to the heart' (Henderson, 1938).

The venous return is also aided by the rhythmic alterations of intra-thoracic pressure with the phases of the respiratory act. It is, however, only in abdominal breathing that the respiratory act aids the return of blood to the heart (Lewis, 1908). These alternating pushes and pulls, produced by muscular action dependent on the tone of the diaphragm and muscles of the abdominal wall, have a minor effect on venous return in comparison with the constant

tonic push of muscle in general. During exercise, more capillaries in muscle become patent and, if muscle is in good tone, more blood is put under tissue pressure. On the other hand, if tone is at a low level, blood filling the capillaries is not pressed out, congestion appears and the heart fails through lack of blood. The fit person whose heart is able so to increase its output per unit of time that adequate blood is supplied to active tissues to meet their increased needs, must have a higher value of muscle tone than the unfit. Experiment shows that healthy young men have a tone in their relaxed left biceps muscle which is capable of withstanding a pressure of 60–90 mm. of water, while patients in bed have an intra-muscular pressure of about 50 mm. H_2O.

Intra-muscular pressure is markedly increased when muscle contracts, so that, as the fibres in muscle shorten intermittently during exercise, the blood is expelled from the venules in the muscles intermittently. This pulsation plays an important part in maintaining the tone of the vessel walls. The hæmostasis produced by immobile standing, shown by swelling of the legs in unfit persons, may be prevented by almost imperceptible voluntary twitches of the calf muscles or even by movements of the toes. Standing rigidly at attention is a severe test of the efficiency of the mechanisms responsible for the venous return to the heart.

Muscular tone is dependent on many factors—adequate blood supply, absence of excess of fatty upholstery, a regular arrival of motor impulses to the muscle controlled from higher centres and a cooling mechanism nicely co-ordinated to the needs of the moment. It is easy to demonstrate that faulty heat loss lowers tone. The avenue by which heat is lost is apparently unimportant, but, unless under the artificial conditions of the laboratory where even loss by radiation can be made the effective sole method of losing heat, the evaporation of moisture from the skin is the usual limiting factor (Mills and Ogle, 1939). Several investigators have shown that the phenomenon known as ' second-wind,' by which a runner experiences a sudden relief from the agony of breathlessness and the leaden drag of weary muscles, is accompanied by sweating. When this occurs, alveolar CO_2 falls, the urgency of breathlessness fades, the head clears and the muscles act with renewed vigour.

Measures of Fitness.—Three means of measuring fitness are thus indicated, and they are interrelated :

(*a*) Tests of recuperative efficiency. The ability of the cardio-respiratory mechanism to return to normal functioning within a limited time after exertion.
(*b*) The ease of heat loss under specified conditions.
(*c*) The value of muscle tone.

(*a*) Tests such as Goodall's, Crampton's, Foster's, McCurdy's and Schneider's, which depend on arbitrary scoring for rise of pulse rate, blood-pressure and respiration rate after exercise, and scoring for the length of time for a return to pre-exercise levels, have a very low coefficient of reliability. Schneider's is the best with an $r = 0{\cdot}4$. McCloy prefers to measure alterations in diastolic pressure and pulse rate on standing erect after lying supine. This had an r between $0{\cdot}8$ and $0{\cdot}9$ in a limited study of healthy and convalescent golfers.

Turner's test, which depends on the cardio-vascular reactions during

standing absolutely still for 15 minutes, has a coefficient of reliability of over 0·9 for adults but yields anomalous results with boys. In Schneider and Crampton's studies of pre-adolescent boys (1935) the boy proved least fit by all other tests was the sole survivor at the end of 15 minutes' standing (with a pulse pressure of 8 mm. Hg !). The others had either given in or had fainted.

The rate at which the oxygen debt is repaid may be used as an index of physical solvency. The fit subject either pays cash to close the transaction or demands short credit. The percentage of the total debt liquidated during 3 minutes after the cessation of exercise is, in the case of the unfit, about 30, while the same subject, in condition, may have discharged over 60 per cent. of his debt. The drawback to the employment of tests of recuperative power is the possibility of overstraining the vaso-cardiac mechanism in the unsound.

(*b*) No large series of experiments has yet been planned to gauge the reliability of this test of efficiency.

(*c*) The value of muscle tone may be determined in various ways. Coffey, Barnum and Henderson (1910) used the knee-jerk as an index of tonus. Even when absolutely uniform strokes of the hammer are applied to the patellar tendon of a co-operating subject, variable degrees of the extent of kick are obtained with successive stimuli. It is a useful method to demonstrate the gross alterations for which these workers used it, but, principally because it requires a trained subject for accurate results, it is not of general utility. The direct reading of intra-muscular pressure (Hellebrandt, 1939) is awkward and somewhat unpleasant for the subject. Several attempts have been made to link creatinine excretion with muscle tone (Schaffer, 1908). 'Other things being equal,' say Daniels and Hejinian (1929), 'the infant who has a high creatinine-length coefficient is the more nearly physically fit.' Daniels, Hutton and Neil (1938) showed that in children up to 6 years of age, those physically fit (private subjects) had higher coefficients (mg. creatinine $\times 1000/ht^3$ in cm.) than the less fit (and less well off) subjects. All with a coefficient below 0·264 they class as 'ill-nourished.' Unfortunately, in these experiments (and many others on older subjects) little or no regard was given to the amount of meat eaten. 'There is no parallelism between the amount of flesh eaten and the increase in the excretion of creatinine. Estimations of the excretion of creatinine, while the subject is on a flesh-containing diet, are quite devoid of value, even though the amount of flesh in the diet is kept constant' (Burns and Orr, 1916). For the same reason, lack of strict control of dietary constituents, the exhaustive work of Jellinek and Looney (1939), on some biochemical constants of thirty men who had been carefully selected and rigorously examined to ensure physical fitness, must be accepted with caution so far as their creatinine findings are concerned.

Noël Paton, in his Presidential Address to this Section at Bournemouth in 1919, put forward the suggestion that the maintenance of muscle tone (and hence of physical fitness) depended in part on the presence in tissue-fluid of small quantities of guanidine or its methyl-derivative. He showed unequivocally that muscle, either of warm- or cold-blooded animals, increased in tone when minute amounts of the salts of this base were administered. Since then much work has been done to elucidate this problem. Sullivan (1935) was able to estimate the urinary guanidines in cases of progressive muscular dystrophy before and during treatment. As the cases improved, under

glycortal medication, simple guanidines disappeared from the urine. More recently, Minot (1938) has successfully treated patients suffering from this disease by oral administration of guanidine hydrochloride; and Dewar, working in my laboratory, has confirmed this (using the tasteless carbonate). Unfortunately, exhaustive search has failed to find a reliable method for the estimation of urinary or blood guanidine, and so, as a test of tone, the determination of the simple guanidines is, at present, unavailable.

Noël Paton thought that the point of action of this alleged hormone was on the motor nerve-endings. Work in my laboratory has shown clearly that the sensitivity of the sympathetic nervous system is markedly enhanced by extremely small amounts of guanidine, and so we assume that the tone of muscle must in part at least depend on the integrity of this nervous system. This view is not invalidated by the alterations in tone reported by Henderson (1938) in a sympathectomised cat. If our view is right, adrenergic fibres must pass to muscle with the motor outflow—an outflow not interrupted by sympathectomy as generally performed.

The sympathetic control of muscle tone has been the subject of many investigations and much controversy. There is a wealth of indisputable evidence that the anatomical sympathetic system plays, at best, a minor part in the direct maintenance of muscle tone and no one now holds the views of Hunter or of Royle. On the other hand, the work of the Orbeli school, amply confirmed by later experimenters from other laboratories, points to the influence of adrenergic nerves on the neuromuscular mechanism. This influence is shown more clearly when the action of the vasoconstrictor fibres is removed by poisoning with ergotoxine. This may be taken to mean that the main function of the sympathetic in the maintenance of muscular tone lies in ensuring effective vasodilatation of the muscle capillaries (Rosenblueth and Cannon, 1935) brought about through the so-called ' nutrition reflex ' (Hess, 1930; Fleisch, 1935). The fit man, with good muscle tone, soon stops the drain on the blood supply to skin and viscera, while the unfit keeps the pallor of skin for some time and may even show signs of acute digestive upset. One may, therefore, test fitness by estimating the degree (amount $\times$ time) of the deprivation of the skin of moving blood.

The responsiveness of the sympathetic arm of the reflex arc depends on the functioning of the cortices of the suprarenal glands (Secker, 1939). This pair of ductless glands with a long ancestral history is absolutely necessary for life and is affected by any undue strain on the reserves of strength. The will to endure, to keep going on, is mental, but the power to force an unwilling body to obey the order of the mind, to exert its last ounce and not die in the last ditch, depends, in the end, on the adequacy of the secretory mechanism of the cortices suprarenales. Animals with grafts of cortical tissues and no medullæ act as normals (Ingle, Hales and Haslerud, 1936). Injection of cortical extract to completely adrenalectomised rats restores voluntary activity to an extent depending on the amount of cortin given (Ingle, 1936). Hypertrophy of cortical tissues follows exercise in the rat (Anderson, 1935). ' Possibly,' says Dill (1936), ' one of the effects of training is to increase the secretory activity of the adrenal cortex.'

The sequelæ of severe muscular exercise under conditions where cooling is inadequate differ only in degree from those of cortical insufficiency, i.e. loss of

muscle tone, increase of blood potassium and lowering of blood sodium both absolutely and relatively. The loss of tone may be due to imbalance between the metallic ions as well as to exhaustion of cortical supplies as it may be mirrored in normal subjects by administration of salts of potassium.

3. *Psychological Tests.*

The fit man carries on his work and his play without an unpleasant degree of fatigue, and so his industrial output may be taken as a measure of his fitness. The amount of work done or the goodness of the work done depends not only on the physical state of the worker but on the state of his mind. It is well known that work which is in itself pleasant or leads to pleasure as a more or less remote result is carried out with an efficiency lacking in more formal performances or in forced work. L. Hill (1898), Gillespie (1924) and many others have shown that the initial cardiac acceleration followed by peripheral and splanchnic vasoconstriction leading to an increased venous return to the heart with consequent cardiac retardation and increased output is mainly psychical in origin. If the work is uninteresting or the movements passive (Martin *et al.*, 1914) these preparatory circulatory changes do not take place and the organism as a whole is thus less fitted to do work. Investigations involving treadmills, stationary running, bicycle ergometers, etc., may thus fail to reveal accurately the efficiency of a subject because of the more or less complete lack of interest of the work once the novelty has worn off. The performance becomes a routine and the efficiency consistent but low. On the cessation of the mental effort, the tone of muscle falls, the peripheral and visceral vasoconstriction passes off and output falls. One of the conclusions, drawn from the results of many exhaustive investigations made in the U.S.A. and in this country, is that good sociological conditions are of paramount importance if good work is to be expected. Even apparently trivial improvements in amenities lead to increased output. For example, the average output of relays per hour in the Western Electric factory at Chicago of 55·7 when lunch was provided by the management, rose to 66·4 when the employees supplied their own lunch. This rate was maintained over two periods of 31 weeks (of the observation period) and was a record (Whitehead quoted by Dill). Hitler realised this principle, in theory at least, when he instituted his ' Strength through Joy ' movement.

Value of ' Stunt ' Tests.—Cathcart places great value on the ability to react rapidly and accurately to changes in the environment. Efficiency in this can be tested by presenting the subject with exercises which demand new co-ordinations as well as motor activity with a performance both easy and graceful. This type of test, as outlined by Brace, McCloy and others, has a coefficient of validity of over 0·8.

Exercise and Fitness.

What, then, can be said of the effect of exercise in maintaining fitness? The Committee of the Health Section of the League of Nations is rather despondent on this matter. They say, ' Up to the present, methods and systems of physical education have not produced any clearly demonstrable

effect on the health of the masses, doubtless because the present state of our knowledge is not as yet sufficient to enable us to base them on accurate scientific data ' (1938).

Properly designed exercises, carefully controlled, can be used to correct faults of carriage, to eliminate uneconomic muscular actions and fit the mildly dysplastic to take their place without shame among the euplastic. The danger of such exercise lies in any attempt to create an ' ideal ' posture, etc., which has no physiological foundation.

Exercise carried on without strain or undue fatigue keeps the body in tone ; and some exercise is considered beneficial to those engaged in sedentary occupations especially, as it increases the venous return to the heart and prevents stagnation in the blood reservoirs and lower limbs. The group of experts of the Commission on Physical Training were therefore enjoined ' to determine the minimum amount of physical training required to ensure the normal health of the individual.'

Exercise designed to ' build muscles ' beyond the needs of that particular person merely leads to increased food intake, and when, because of age or lack of opportunity, the amount of exercise is decreased, fibrous and fatty degeneration and infiltration takes place. While it may be ' better to have lov'd and lost,' it is certainly not better to have exercised and stopped.

Probably the main beneficial result of keep-fit classes and similar movements is the inculcation of a spirit of independence, personal confidence and pleasure in performance. Although ' the healthy body works in silence ' (Carrel), the fit person has a keen sense of the enjoyment to be obtained from suitable exercise. The physiological foundation of the exhilaration resulting from exercise—an exhilaration not entirely due to a decreasing handicap at golf or competitive improvement at other games—would be a suitable and profitable study for ambitious politicians and others.

While it is true that one cannot assess a man's efficiency till his whole life's story has been unrolled (and then it is too late to do anything about it), one should be able to establish norms related to age and sex. The recent Military Service Act provides an occasion for the audit of the nation's young manhood, and, provided suitable tests are applied by properly trained examiners, a beginning will have been made to the collection of facts and figures from which much may be learned.

There is no doubt as to the improvement in mental and physical fitness that results from wise physical training, co-operative effort and good feeding such as that obtained in military camps of the best type. Such training may go far towards reconditioning some of the youth of the country. The American Department of Labour, in a report (1935) on two years' experience of civilian conservation camps, says, ' Thousands of actual case records reflect the fact that the C.C.C. men have returned to their homes definitely benefitted physically and mentally ; their outlook toward the future is brighter, their sense of self-reliance and their ability to adjust themselves to economic conditions is stronger.' To this tribute to wise and varied physical, mental and moral education one may add the results of a short experiment in effectively reconditioning a selected number of rejected recruits for our own Army. ' My predecessor started a depôt for training a limited number of men who were below standard and, as a result, . . . 576 of the 600 . . . have

reached the full standard of fitness ' (Right Hon. L. Hore-Belisha, Devonport, 1937).

While not in any way detracting from the importance of work of this type on men during late adolescence and early maturity, one may ask why the audit is not made earlier in the course of our national business of turning out citizens—taken early before the debit balance of wasted lives becomes so large that strenuous measures have to be taken to safeguard our interests. No factory whose products were good, bad and indifferent would exist long before the shareholders were demanding an inquiry and a change of directorship.

Our national strength lies in our men and women and not in the machines that they tend or the battleships that they man. To be really great a State must have citizens fit in body and also in mind. ' The health of the intelligence and of the affective sense, moral discipline and spiritual development are just as necessary as the health of the body and the prevention of infectious diseases ' (Carrel).

To ensure this would cost money, but so does radium. The chief use of this rare element is to prolong the life of the aged ; should we not be equally ready to foot a bill which would make young lives more fit to bear hopefully and without undue strain the heavy burden their ancestry has laid on them? —so that with Walt Whitman we may see

' Journeyers gaily with their own youth,
Journeyers with their bearded and well-grained manhood,
. . . . . .
Journeyers with their own sublime old age :
Old age, calm, expanded, broad with the haughty breadth of the universe.'

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APPENDIX (*see* p. 404).

From the report of a debate in the House of Commons (July 20, 1939).

'Mr. Chamberlain said: "I am presenting a very serious argument. What is going to be the result of this increased expectation of life, coupled with the diminution in the birth-rate, which is going on at the same time? In 1931, the number of persons of 65 years and over was, in proportion to the number of people between 15 and 65—the earning age—as 11 to 100. In 1955, that will have risen to 16 to 100, and, in 1975, to 20 to 100. It may be said that that is a long way off and we shall not know anything about it, but surely we ought, if we have a proper sense of responsibility, to consider what is going to be the effect on the next generation of anything that we may be doing to-day. I would put this point to the House. The implication of the figures I have given is this: That as time goes on there will be an increasing proportion of the population who will be eligible for pensions and to whom pensions will have to be paid, and there will be a decreasing proportion of the population who will be earning wages and therefore able to make contributions to pay them."

'In 1930, after the Contributory Pensions Act was passed, the cost to the Exchequer was £46,000,000. The estimates for the current year showed a charge of £69,000,000, and in the course of the next forty years the estimated annual cost will rise to £115,000,000 at the present rates of payment.'

SECTION I.—PHYSIOLOGY

COMMUNICATIONS

Discussion on The problem of pain. (Held in the Department of Physiology, Bute Medical Building, St. Andrews.)

Prof. D. Waterston.—The problem of pain.

The advances in our knowledge of pain in the past fifty years, and especially the work of Sir James Mackenzie. His concept of ' referred pain ' or the viscero-sensory reflex, and the mechanism of its production.

The response of somatic tissues and of the viscera to pain stimuli.

The theory of the production of pain by ' over-stimulation ' of afferent (sensory) nerves and that of the existence of pain nerves.

The work of Sir Thomas Lewis and the theory of a ' nocifenser system ' of nerves, and the production of a ' pain-producing substance.'

The relation of the cerebro-spinal and of the autonomic nerves and of the cortex and thalamus.

Recent views on the peripheral and the central causation of pain.

Prof. John Morley.—The dual mechanism of pain in disease of the gastro-intestinal tract.

Mackenzie's observations on insensitivity of the gastro-intestinal tract, and his rejection of Ross's theory on splanchnic pain. His elaboration of Ross's theory of radiation of pain from viscera to parietes through an ' irritable focus in the cord.'

Mackenzie's inability to distinguish between referred pain from parietal peritoneum and from intra-peritoneal viscera.

Critical examination of Mackenzie's theory of abdominal pain.

Ross's view of splanchnic pain is supported by experiments on man.

Lack of clinical evidence of reflex rigidity and tenderness in pure intestinal obstruction, e.g. in strangulated hernia or gallstone obstruction. Clinical findings in early acute appendicitis incompatible with Mackenzie's theory.

Importance of radiation of pain to shoulder-tip on stimulation of phrenic nerve endings, because 3rd, 4th, and 5th cervical segments have no visceral connections. Peritoneo-cutaneous radiation of pain and peritoneo-muscular reflex explain deep tenderness and rigidity in abdominal wall. Recent work of Kellgren and Lewis.

Importance of nerve-blocking experiments, and doubts concerning the ' irritable focus ' theory.

Pain from urinary system harmonises with Mackenzie's views though gastro-intestinal pain does not.

Prof. B. A. McSwiney and Dr. B. M. Unkauf.—Visceral afferent fibres.

Dilatation of the pupil in the cat anæsthetised with chloralose and reflex changes of blood pressure in the spinal and decerebrate cat and in the cat anæsthetised with chloralose have been used as indices of visceral afferent impulses. It must be pointed out, however, that these methods do not indicate the character of the sensation.

The gastric and duodenal mesenteries are supplied by the vagus and splanchnic nerves, while the jejunal mesentery appears to be supplied by the splanchnic nerves. The mesenteries are sensitive to traction.

The body of the stomach, pyloric antrum and pyloric sphincter are sensitive to distension and are supplied by afferent fibres in the vagus and sympathetic nerves.

The stomach and duodenum are supplied by afferent fibres from the right and left vagus nerves and the right and left splanchnic nerves. The jejunum and ileum are much less sensitive to distension than the stomach and duodenum. The right and left splanchnic nerves appear to be the main afferent pathway from these regions.

The ileo-colic sphincter and the large intestine are also sensitive to distension. The sphincter is supplied by afferent fibres from the right and left splanchnic nerves and from fibres which enter the spinal cord by the dorsal roots of the lower thoracic and the upper lumbar segments. The large intestine is supplied by afferent fibres which join the lumbar sympathetic chains and enter the spinal cord by the dorsal roots.

The highest and lowest levels of entry into the spinal cord of the afferent neurones of the pupillo-dilator reflex are shown—

Area stimulated.	*Upper limit.*	*Lower limit.*
Fundus and body of stomach	T3–T4	T13
Pyloric antrum	T5	T13
Pyloric sphincter	T5	L1–L2
Duodenum	T6	L1
Jejunum	T7	T12–T13
Ileo-colic sphincter	T7	L2
Large intestine	T7	L2

Visceral afferent fibres from either splanchnic nerve, and somatic afferent fibres from the intercostal nerves ascend contralaterally and ipsilaterally in the lateral columns of white matter. Those pupillo-dilator fibres in the splanchnic nerves and in the intercostal nerves which ascend contralaterally, cross the spinal cord in the segment above that by which they enter the cord.

The function of the visceral afferent fibres is discussed.

Prof. J. Chassar Moir.—Observations on uterine pain.

There is evidence that the uterus behaves like other visceral organs with regard to sensibility. It can be cut, crushed, or seared with cautery without causing pain to the conscious woman. Vigorous scratching or tearing of the mucosa will, however, cause some discomfort, and in this the uterus seems to differ from other hollow organs. Distention of the pregnant or non-pregnant uterus, and especially stretching of the tissue in the neighbourhood of the internal os, provokes intense pain. While there is no clear evidence to show whether uterine pain is or is not a true visceral sensation, it is fairly certain that the pain is, in part, a referred sensation. For example, certain forms of stimulation to the cervix will at once cause severe pain which the patient describes as being felt over the sacrum. There is strong evidence that the pain of labour is not due to muscular contraction *per se*, but is largely caused by distention and deformity of muscle of the lower uterine segment and cervix. In certain rare circumstances intense uterine spasm may also cause pain. This has been seen in a few instances after delivery as the result of an injection of pituitary extract. The severe pain of spasmodic dysmenorrhœa is also probably caused by uterine muscle contracting, and continuing to contract, in the absence of a free blood supply. The intra-uterine pressure in such cases may exceed the patient's blood pressure. Such pressures are far in excess of those reached during labour.

Mr. T. F. Todd.—Intra-thecal alcoholisation.

Intractable pain is relatively rare and is most frequently found in association with advanced malignant disease. Previously morphia was the only remedy, but

to-day surgical methods offer an alternative treatment which avoids the depressing sequelæ of morphinism.

Assessment of pain.—Objective criteria of pain assessment are lacking. Can the physiologist devise some instrument like the Summers ' Pathometer ' to enable us to estimate the degree of pain ?

Personal Experiences with Intra-thecal Alcohol.—Approximately fifty cases have been given intra-thecal injections of alcohol ; all were suffering from pain in the pelvis or lower limbs associated with advanced malignancy, mostly carcinoma of the cervix. The results have been very gratifying. In over three-quarters of the cases more or less permanent relief of pain has been obtained. In half the remainder there has been an appreciable degree of relief and in four or five cases only has there been a failure to give relief. The failures have been associated with bone metastasis, spinal cord compression, or established morphinism. The technique is not complicated and if care is taken complications can be mostly avoided. The average duration of relief is three to four months.

* * *

Discussion on physical fitness.

Col. R. B. Campbell, C.B.E.—The psychological aspect of physical education.

I. Physical education the science of movement—movement and life—the scope of physical education in the conduct of life.

II. The upward trend of movement in the evolution of mankind—the significance of the upright position—the advent of the thumb and its influence in the development of the mind—the training of the senses and their force in physical education.

III. The influence of thought on the functions of the body—the power of the emotions in physical action—the unity of mind—body—spirit.

IV. The ethics of play—games and temperament—selection of games—the principles of training.

V. The spirit of self-effort—character and training—progressive stages in individual development—physical education to fit in with the rhythm of life.

VI. Mind and movement—thought and action—physical expression and its psychic equivalent—psychological interpretation of voluntary movement—the moral aspect of physical education.

VII. The measurement of movement—physical ability tests—their value and purpose in the direction of physical education—their stimulus to self-effort. Self-effort and leadership—leadership and team-work—team-work in education.

Miss Helen Drummond.—The contribution of physical education towards physical fitness.

Is physical education really necessary in childhood and adolescence ?

The dependence of success upon the attitude of the child himself, the home and the school.

Physical education in adult life. The fitness movement.

The training and approach to work of the teacher or leader.

Prof. A Hemingway and Mr. H. R. Noltie.—Respiratory exchange measured during distance running.

Oxygen consumption and carbon dioxide output were measured, using expired air samples collected by the Douglas Bag method, during steady running for eight to sixteen laps on a quarter-mile cinder track.

Despite a steady rate of running the respiratory exchange was by no means

steady. The oxygen retention tended to fall off after about eight laps though the carbon dioxide output remained fairly steady.

After seven weeks' absence from track running, though not from other forms of exercise, oxygen consumption was found to rise more slowly than before, whilst the carbon dioxide production was no higher and at a maximum about the sixth lap.

* * *

Dr. F. W. Edridge-Green, C.B.E.—The double function of the ocular muscles.

The most important part in photography is the film, and a fresh film is required for each photograph. This is accomplished in the eye by the pressure caused by the contraction of the eye muscles. If a light be attached to a scale in a dark room and a point three feet to the right be marked with a peg, and the light be looked at with one or both eyes for one or two seconds from a distance of ten feet, and then the eyes be directed at the peg, it will be noticed that the negative after-image of the light is seen on the peg, but the positive after-image has rapidly passed it to the right. The eyes being directed towards the peg, it will be noticed that the positive after-image comes rapidly back towards the peg. The first part of the experiment has been described before, and it is evidently due to the contraction of the eye muscles pressing on the eye and moving the photo-chemical fluid, thus causing a separation of the positive and negative after-images. The second part of the experiment appears to be due to the cessation of the pressure on the eye causing the photo-chemical fluid to flow in the opposite direction. It should be noted that the pressure is in the opposite direction to the movement of the image ; thus, when the pressure is to the left the image moves to the right, corresponding to the new position of the fluid in the retina.

This and numerous other experiments can only be explained by the author's theory of vision which assumes that the cones are the sole percipient elements and that the rods are the nerve elements which sensitise and regulate the photo-chemical film.

MEASUREMENT IN PSYCHOLOGY

ADDRESS TO SECTION J—PSYCHOLOGY

By R. J. BARTLETT

PRESIDENT OF THE SECTION

In the opening paragraph of *Psychology down the Ages* Prof. Spearman concludes a list of difficulties, facing any who seek to define psychology, with the questions : ' Do the data at its disposal include what can properly be called " measurements " ? Is it, or can it ever hope to be, or should it as much as try to be, a systematic science at all ? ' Dr. William Brown, in the realm of Medical Psychology, answers the first question in the negative. Forced into metaphysics, he writes : ' Determinism, although a postulate for psychology, cannot be accepted as anything proved. In physical science there is empirical proof of it to a certain extent through measurement. By measurement we can prove to a certain extent, within certain limits of error, the conservation of

mass, the conservation of energy . . . But there is no measurement of that sort possible in psychology . . . The observations of psychology are primarily qualitative, not quantitative.' [1] But the writer of *Essentials of Mental Measurement* could not leave it there. He added a footnote : ' But mental measurement, in a derived form, is possible in the domain of mental tests and of the psycho-physical methods.'

The conflict between philosophy and experimental psychology, thus exemplified, is of long standing. Malebranche argued that mental states could be distinguished qualitatively, but not quantitatively. Leibniz declared that mathematical treatment was impossible in psychology as it lacked continuous magnitudes. Kant said that psychology possessed no mathematical magnitudes for the reason that, ' whereas the phenomena of matter possess two variables, space and time, those of mind have only the single one, time.' [2] For these and many later philosophers psychology possesses neither measurable phenomenon nor the means to measure. Still worse ! Some physicists seem to have reached the same conclusion. For them measurement is impossible in psychology.

In 1932 a committee of Sections A and J was appointed to consider and report upon the possibility of quantitative estimates of sensory events. Last year this committee ended its interim report [3] with a request ' for reappointment to consider whether the views put forward (therein) are, or are not, irreconcilable.' They now report that agreement seems impossible. If all measurement must conform to the Laws of Measurement enunciated by Dr. Campbell,[4] and, in particular, if the second law can only be satisfied by the physical juxtaposition of equal entities, then sensation-intensity cannot be measured. Yet this standard would have imposed a severe handicap in the early days of natural philosophy, and, maybe, some sciences must still be allowed greater latitude. The alternative would seem to be the coining of a new title for much that is called measurement.

Notwithstanding criticism from philosophy and physics the word measurement is deeply imbedded in the literature of psychology, and of late years its use has been greatly on the increase. Experimental psychology is little more than fifty years old. Galton's *Inquiries into Human Faculty* appeared in 1883, Wundt went to Leipzig in 1875, Weber died in 1878 and Fechner in 1887. Since then an ever-growing body of workers has been applying experimental method to psychological problems and developing its own methods of measurement and mathematical treatment of data obtained. Contemplating this work against the declaration that measurement is impossible in psychology Prof. Spearman comments : ' But the path of science is paved with achievements of the allegedly unachievable. And in point of fact, mathematical treatment is perhaps just the region where psychology has made its steadiest and most surprising advances.' [5] My task is to attempt a review of experimental psychology that will reveal the senses in which the word measurement is being used by psychologists.

[1] *Psychological Methods of Healing*, p. 51 (1938).
[2] Spearman, *Psychology down the Ages*, p. 89 (1937).
[3] Report, 1938, pp. 277–334.
[4] Campbell, N. R., *Measurement and Calculation* (1928).
[5] *Psychology down the Ages*, p. 89 (1937).

First, however, a few words on the meaning of *measurement* as given in the *Oxford English Dictionary* may not be out of place. Perhaps the nearest approach to the physicist's meaning, there given, is : ' To ascertain the spatial magnitude or quantity of (something) ; *properly*, by comparison with some fixed unit.' At the other extreme we find Hobbes' ' Men measure, not only other men, but all other things by themselves,' and Jeremy Taylor's ' Measure your desires by your fortune.' Between these meanings we find : ' That by which anything is computed or estimated ' ; ' To appraise by a certain standard or rule or by comparison with something else,' and, of still greater interest in view of the immaterial nature of things mental : ' To estimate the amount, duration, value, etc., of (an immaterial thing) by comparison with some standard.' It would seem that ' appraise ' and ' estimate ' are acceptable synonyms of ' measure ' and that the common element in the definitions is ' comparison.'

In workaday science the comparison is with a numbered scale, and results are expressed by number and name, as ' three inches,' ' 65 degrees,' ' 43 years 6 months.' A scale built up by the addition of equal standard units is the ideal, but to say that measurement is possible only by such scales, would seem to be an unhelpful limitation of the meaning of the word. If physics has reached the stage where the ideal can be achieved, it may be desirable to speak of measurement by comparison with its perfect scales as ' physical measurement ' while leaving less fortunate sciences to work with their, possibly crude, approximations.

When we turn to actual measurements being made in psychological laboratories we find in use metre scales and foot rules, balances and weights, chronoscopes and stop watches, resistance boxes, galvanometers, photometers and any other measuring instrument that ancient wisdom or modern physics has made available and happens to be of service in the task in hand.

One general group of tasks consists in measuring the results of bodily activity carried out under controlled conditions. Take as an example the product of a person's behaviour when asked to draw lines on blank foolscap paper of length equal to half the width of the paper. In one experiment 2,048 such lines were drawn and measured. It is probable that no two lines were exactly the same length, and that measurement to 0·01 mm. would have proved this, while obscuring a law binding them together.

Choosing a coarser unit, we measure to the nearest millimetre and find 92 lines of 103 mm. length at the modal value of results scattered from 69 to 135 mm. Relative to the material our unit is still fine, so by addition we find the numbers of lines that would have fallen into each group had we measured with units 2, 3, 4, 5 and 6 mm. respectively. With increase of the size of unit the numbers approximate more and more closely to a smooth curve. Further, as we take out the figures for measurement with a unit of 6 mm., we recognise in them an approximation to the terms of the binomial expansion $(1 + 1)^{11}$. Then, using the slightly smaller unit of $5\frac{2}{3}$ mm., we obtain the curve of Fig. 1 with its close approximation to the binomial point curve. For a particular case we have established the fact that by suitable choice of unit our experimental data fall into groups closely approximating to the binomial distribution of their number, 2048. And this is but a particular case of a general law.

The Gaussian continuous function, commonly called the *normal curve* or *curve of error*, in the form

$$y = \frac{N}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}}$$

gives close approximations to the values of binomial distributions, and is usually taken to represent the law of distribution of the results of the bodily expression of mental intention. The frequency with which results of this nature

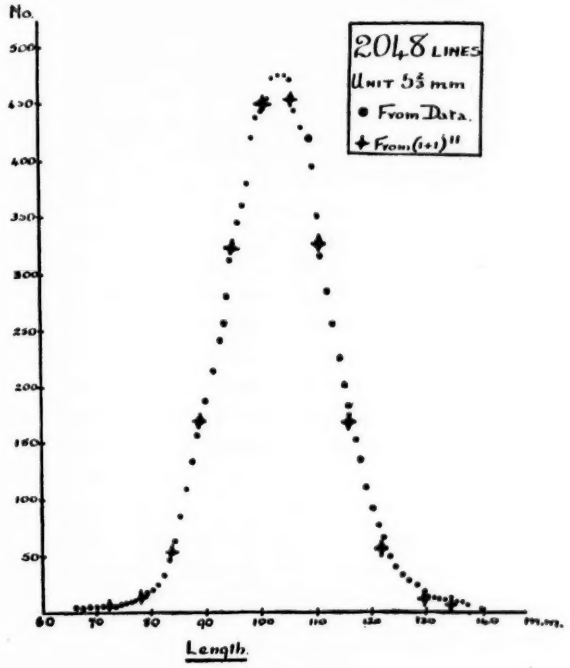


FIG. 1.

are obtained in psychological experiments leads to the conclusion that an appreciable scatter is an essential feature of our data, and that, while the old time physicist or chemist can rest satisfied with the mean of two determinations, we must make at least 50 before we can be reasonably sure of the values of our constants. Experimental psychology could have made little progress without accepting what Dr. Darwin, last year, in his presidential address to Section A, called ' the fuzziness inherent in absolutely all facts of the world,' when he was arguing ' that the subject of probability ought to play an enormously greater part in our mathematical-physical education.' [6]

We have seen that Kant reached the conclusion that mind had but one variable—time. Without accepting his conclusion, we can concur in the importance of the time factor in mental happenings, and appreciate the part played in psychology by the Wheatstone-Hipp Chronoscope, stop watches and

[6] *B.A.A.S. Report*, 1938, pp. 32, 33.

other instruments for measuring and recording time intervals. The human factor with its individual differences forced itself upon the attention of astronomers in 1796, and led to acceptance of the ' personal equation ' as a necessary correction to an observer's data. Physiologists became interested and sought in reaction experiments the ' velocity of the nervous impulse.' Later, psychologists took up the study of the duration of simple mental processes. The so-called simple reaction time is the time taken between the giving of a stimulus and the recording of awareness of the resulting sensation. The significance of any difference obtained depends upon the accuracy with which the mean has been obtained and the scatter value of the individual readings. It becomes necessary to consider the use of the probable error.

This measure of scatter became popular in psychology because of its readily remembered relation to the data. Within the limits defined by the probable error half the cases fall. Having determined the probable error of a case as the semi-interquartile range, by counting, or as $0{\cdot}6745\ \sigma$, by calculation, the probable error of the mean is obtained by dividing this by the root of the number of cases, and the probable error of the difference between the means of two different sets of reaction times can be determined by taking the root of the sum of the squares of the probable errors of the two means. The ratio of the actual difference of means to the probable error of that difference is a measure of the significance of the difference.

Starting from comparatively simple beginnings, reaction times of more and more complex mental activities were determined and the chronoscope has become for the psychologist what the balance is for the chemist. The nature of the associative links of memory are linked to differences in the ' association time ' and medical psychology has found a useful tool in the stop watch used with the Jung or some other word list. In many experiments, time is the indicator of difference or agreement ; but what the differences are due to has to be discovered by introspection and the analysis of records of many introspections obtained under experimental conditions. When the experimenter reaches the stage of being able to prophesy the nature of the introspection not yet disclosed he is justified in accepting the reaction time as an indicator, not only of a difference in experience, but also of the nature of that difference.

Our concern till now has been with the products of mental activity and the duration of experiences. Psychology, however, is concerned more with the nature of the experience than with its effect on the environment or its bare duration, and so the question arises as to whether sense experiences have quantitative characteristics other than duration. The general conclusion is that they have. Ward writes : ' A single sensation we find has not only a determinate quality but it is also quantitatively determined in respect of intensity, protensity (or duration) and extensity.' [7] Titchener speaks of ' intensity, clearness and duration,' [8] and Spearman adds ' speed,' pointing out that ' A man's perception of one and the same black spot may either be clear, intense, quick and persistent, or else the reverse of these. And in this way the total experience in the two cases may become wildly dissimilar. But the objective blackness of the spot remains approximately constant.' [9]

It would seem undeniable that intensity is a characteristic of sensory experi-

[7] *Psychological Principles*, p. 105 (1918).
[8] *Textbook*, p. 52 (1919).
[9] *Psychology down the Ages*, p. 262 (1938).

ence, and for this reason it is, at the least, unfortunate that Stevens and Davis should, quite definitely, have handed it over to physicists as exclusively a property of the thing cognised.[10] In the words of Titchener,[11] ' Intensity is the attribute to which we refer when we say that a given sensation is brighter or duller, louder or fainter, heavier or lighter, stronger or weaker, than another sensation. In making such comparisons, we think of the sensation as possessing the same quality : both are blue, both are *bb*, both are pressure, both are cold or salt or asafœtida : but these two sensations, of the same quality, lie at two different points upon a finite scale of sensation degrees, which begins at a lower limiting value and rises to a maximum. The more intensive sensation is placed higher up, the less intensive lower down, upon the scale of intensities.'

When we attempt to evaluate this quantitative element in sensation we are met with difficulties. First comes the fact, already referred to, that the same material object may be perceived by sensations that vary greatly in intensity. The intensity of experienced sound of an express train is as a rule different for a passenger comfortably sitting in it and for a would-be passenger standing on the platform as it rushes through a station. The intensity of the noise of a ticking clock sinks below the threshold when we are engaged in an absorbing task, but the energy output of the clock remains reasonably constant. The same source of stimulation occasions different intensities of sensation according to the subjective attitude of the recipient of the energy falling upon the sensory organs. To secure consistent results it is necessary to control the conditions, and in experiments involving sensation-intensity this is done by arranging that the subject shall give undivided attention to the stimuli. The maximal intensity thus obtained is accepted as constant for the given stimulus.

Normally we do not discriminate the intensity of the sensation, nor are we interested in the particular sensation itself. Our interest may be in the pleasure tone of the whole sensation complex, as when enjoying music or a glorious bank of flowers, but, more often, our interest is in the properties of the external objects that occasion the experience. The lightning's flash, the trumpet's blare are ominous portents, rather than intense sensations. This preoccupation with the things of the external world has given us science but makes introspective analysis of experience difficult. It endows sound, light and matter with ' intensity ' which we proceed to measure with acoumeters, photometers and a balance. For the psychologist, however, these measurements are only of interest so far as they may help to throw light on the problems of sensory experience.

Early in the life of experimental psychology the smallest change in the stimulus value that could be appreciated in sensation became the subject of inquiry and, for the determination of this difference threshold, difference limen, least perceptible difference or just noticeable difference, the psychophysical methods were developed and gave to psychology ' a technique whose wide serviceability does not even yet seem to be fully appreciated.' [12]

Weber, experimenting with weights, reported in 1834 that ' If we are comparing by touch two weights, the one of 30 and the other of 29 half ounces, the difference is not more easily perceived than that between weights of 30 and 29 drachms . . . Since the distinction is not perceived more easily in the former

[10] *Hearing*, p. 110 (1938). [11] *A Textbook of Psychology*, p. 53 (1919).
[12] Spearman, *Psychology down the Ages*, p. 90 (1937).

case than in the latter, it is clear that not the weights of the differences but their ratios are perceived.' [13] In this way was first stated the law that the ratio of the just noticeable difference in the value of the stimulus to the value of the stimulus is, within certain limits, a constant. From the fact that the same law was found to hold for seen lengths of line Wundt passed to the general law—a bold use of inductive method. It was left to Fechner to develop the psycho-physical methods and to put the law on a sound basis. He went further : on the basis of the assumptions that a just noticeable difference of sensation is a quantity of sensation and that all just noticeable differences are equal, he transformed Weber's statement of the facts into a law expressing the relation of sensation-intensity to stimulus quantity in the form that sensation-intensity was proportional to the logarithm of the stimulus value.

The theoretical implications of this law are still matter for dispute. After seven years' discussion some members of the sensory events committee are unable to accept Delbœuf's contention that, while it may be true that sensation-intensity cannot be measured, ' sense-distance ' can. On the way to agreement to disagree, however, the committee did valuable work. In addition to securing statements of the grounds on which certain physicists state, and some psychologists agree, that in no reasonable sense can sensation-intensity be measured, they have secured a critical survey of work on sound intensity by Semeonoff of Edinburgh and a summary of work at Cambridge, by Craik and others, on conditions controlling sensation-intensity results.[14]

Interesting work carried out in the physiological laboratory of Cardiff was also reported to the committee. Results obtained there by Gage [15] showed an apparent lack of consistency in the judgments of his subjects that appeared to invalidate much, if not all, results obtained by psycho-physical methods. For a time the position looked serious, although psychologists suspected that some form of ' constant error ' was present and responsible for the results. This would seem to be the case, for repetition of the work, by Newman, Volkmann and Stevens [16] at Harvard, under slightly different conditions, gave results consistent among themselves.

The methods used in these experiments depend on the judgment of equality of ' sense-distances ' that are supra-liminal. The stimuli corresponding to the sensations limiting the ' sense-distances ' are determined by one of the psycho-physical methods, but in view of the nature of the task, it has become customary to speak as if the method of ' equal appearing intervals ' or of ' mean gradations ' were an independent method. One form of the experiment consists in finding the value of stimulus that causes a sensation judged by the subject to be half-way between sensations caused by two other stimuli, and has been termed the ' method of bisection.' Using this method, Gage found the loudness value of a variable tone that appeared to be half-way between the loudness of two other tones. He then bisected the upper and lower halves respectively, and, having found the stimulus values of the one-quarter and three-quarter ' sense-distances,' proceeded to bisect this one-quarter to three-quarter distance and found that the value so obtained was consistently higher than that given by the original bisection. A possible deduction is that the

[13] Quoted Titchener, *Experimental Psychology, Instructor's Manual, Quantitative*, p. xvi (1905).
[14] *B.A.A.S. Report*, pp. 278–296 (1938).
[15] *Proc. Roy. Soc.*, B, 116, pp. 103–19 (1935).
[16] *Amer. J. Psychol.*, 49, pp. 134–137 (1937).

method is useless and results obtained by it in the past valueless. Another possibility is that we have the cumulative effect of a small positive ' constant error.' The results of Newman, Volkmann and Stevens support the second alternative.

Weber's law appears to be true for a limited range of stimuli only. When we pass out of the zone of sensation to which we are accustomed, our ability to judge of equality becomes subject to an increasing error, and our judgment of difference, as usually determined, includes this error. As a result the ratio of just noticeable difference to stimulus rapidly increases in value as we recede from the central zone. The laws governing this increase became of interest to physicists engaged in work on noise and illumination, and led Sections A and J to hold a joint meeting in York in 1932 and then to collaborate in the work of the Sensory Estimates Committee.

In preparation for that York meeting I carried out a series of experiments on judgment of equality and difference of lifted weights, the most interesting of which were carried out with geometric series of weights. In weight lifting experiments, a subject, having lifted first one weight and then another, passes a judgment of heavier, equal or lighter on the second weight as compared with the first. He compares two past sensation experiences, and it must be on the basis of their values as preserved in memory. Any change that takes place in these memories will affect the first experience more than the second. Constant errors are due to these facts. When two objectively equal weights are lifted, the second weight is consistently judged either heavier or lighter than the first, except over a small range the absolute value of which depends upon the nature of the objects being used. For weights smaller than those of this central zone the second weight seems heavier than the first, while for weights above the zone the second weight seems lighter. In many psycho-physical experiments the effects of such errors are neutralised in order to reach what is known to be objective equality. Thus, if working with weights in cans of such dimensions that a 10 oz. can lifted first is matched with a 12 oz. can lifted second, it will be found that the 10 oz. can lifted second is judged equal to a can of approximately 8 ozs. Taking the mean of 12 oz. and 8 oz. we arrive at the actual weight, 10 ozs., the one ' error ' balancing and cancelling the other. If, however, we work more carefully, we may find that the approximately 8 oz. weight is really $8\frac{1}{3}$ ozs. and the mean becomes 10·17 ozs. Our compensation is not exact : a residual ' error ' remains. An ' error ' of that nature will explain the apparent inconsistency of Gage's results. Weber's law demands that the arithmetic mean of the older sciences be replaced by the geometric mean in psychology.

Returning to our experiments with geometric weight scales : the chief series was composed of flat circular aluminium boxes 4 cm. in diameter and 2 cm. deep, of weight equal to $4\ (1{\cdot}03)^{n-1}$ gms., where n is the series number of the box. Working with a subject who had had experience with other series, it was found that the centre of the zone where he judged equality of weight correctly was box 55 and that this zone was about 30 boxes wide. Below box 40, boxes were matched by boxes objectively heavier, and above box 70, boxes were matched by objectively lighter boxes. Working with one hundred boxes, it was found that the regression was more marked with the lighter weights than with heavier ones. In an attempt to secure as great a difference at the upper end as at the lower the scale was enlarged to 121 members, but the results

were disappointing. The difference obtained on weight 121 was no greater than the difference obtained six days earlier with the then heaviest weight, No. 100. The series was then pushed to the limit possible, which gave weights up to No. 130, but again the increased weights failed to produce an increase in the maximum difference. When, however, the work done on the three different days was distinguished, it was found that the explanation of this apparently unsatisfactory result was that the subject's central zone was steadily gaining towards the heavy end while it remained fairly constant at the lighter end. The results are given in diagram form in Fig. 2. It will be seen that the figures of the second and third day respectively give the same general trend as those of the first day but shifted along the horizontal axis. The curve of the

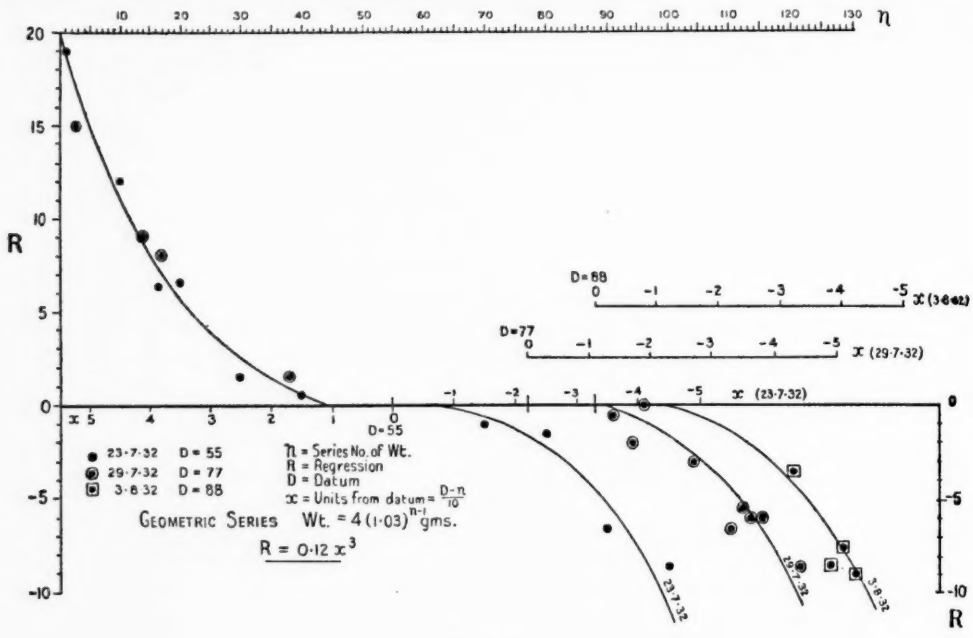


Fig. 2.

first day balances about weight 55 and the heavier end curves for the second and third days are similarly related to weights 77 and 88. The curves suggest a cubic increase in the regression, reasonably well expressed by $R = 0{\cdot}12x^3$, where $x = \frac{D - n}{10}$ and D is the datum value, 55 for the first day and 77 and 88 for the higher values on the second and third days.

One method we used separated the weights, when compared with a selected one of their number, into weights heavier, lighter and equal. The size of the zone of equality is a measure of the sensitivity at that part of the scale, and as the scale is a geometric one, equality in the size of this zone at various parts of the scale would mean agreement with Weber's law. We found that the zone of equality was largest at the light end of the scale and slowly decreased in value as the scale is ascended. Judgment is most difficult at the lower end and easiest at the upper end. To reckon the difference from the best equal value

instead of from the standard stimulus value is in accord with the subjective sensory basis of the judgment. The scatter error on equal judgments, not the constant error, is a measure of sensitivity. But, if the scatter and constant errors are combined, the result will appear as a rapid increase in the value of the Weber ratio as we pass away from the central zone to which we are adapted.

Most, if not all, the work on the variability of the Weber constant has been on crude threshold values composed of the constant error and scatter error. The law was criticised very early and, from various possible tables of figures, consider those of Biedermann and Löwit [17] for pressure. Expressing the ratio as a decimal, instead of a vulgar fraction as was common in the early days, we obtain the table below.

Pressure.

Absolute weight W grams.	Just noticeable difference $\triangle$ W grams.	Ratio $\frac{\triangle W}{W}$.
10	0·7	0·0700
50	1·7	0·0340
100	2·4	0·0240
200	3·6	0·0180
300	4·6	0·0153
400	5·2	0·0130
450	6·5	0·0144
500	25·5	0·0510

Plotting the ratio against the weight, we obtain Fig. 3, in which, instead of a straight line parallel to the weight axis, a roughly U-shaped curve is given; from which can be deduced, for this particular experiment, that there is an approximation to Weber's Law for weights between 100 and 450 grams, but that above and below the 'quotient of sensitivity' rapidly increases in value. Such curves are scattered throughout the voluminous literature on the subject, the stimulus scale, however, being the logarithm of the stimulus value. Several of these are given in Selig Hecht's contribution to Murchison's *Foundations of Experimental Psychology*.[18] In his diagram for illumination intensity,[19] founded on work from 1865 to 1918, the left limb of the curve resembles the curves of Fig. 2, and reading from the curve values of $\frac{\triangle I}{I}$ and log I, cubing the second and multiplying the first by 120, we obtain the table on page 432.

We conclude that underlying the whole controversy is the fact that the experiments have measured, not the sensitivity of sensory discrimination, but rather the 'constant error' due to regression of the memory image of the first stimulus towards the values of the central zone of adaptation.

[17] See Ladd, *Physiological Psychology*, p. 368 (1896).
[18] Pp. 216–72. [19] P. 246.

Much work has been done on bodily and mental work, and results obtained have found direct application in industry. We cannot now deal with the way in

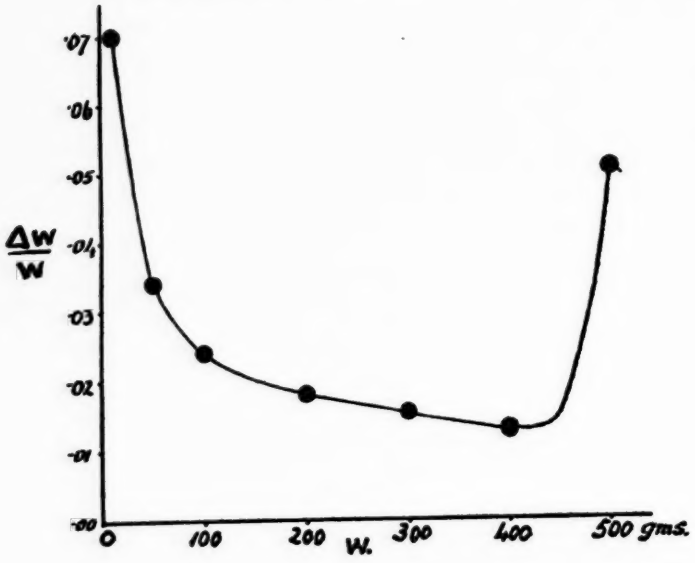


FIG. 3.

which measurement enters into this work, but must spare a moment to call attention to extremely interesting theoretical matters that arise from the work

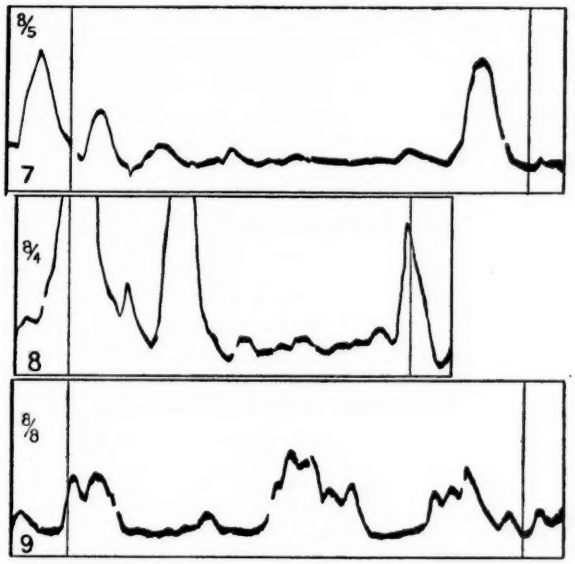
Illumination Intensity.

$\frac{\triangle I}{I}$	log I (millilamberts).	$(\log I)^3$ (to nearest unit).	$\frac{\triangle I}{I} \times 120$
0·7	4·4	85	84
0·6	4·2	74	72
0·5	3·9	59	60
0·4	3·6	47	48
0·3	3·3	36	36
0·2	2·9	24	24
0·1	2·3	12	12

of our Recorder, who finds, in the fluctuations always recorded in work curves, the sum of a number of geometric waves, all having a common factor in their periodicity and commencing at a common datum.[20]

[20] S. J. F. Philpott, *Fluctuations in Human Output. Brit. Psych. Soc. Monograph*, VI, 17 (1932). *A Theoretical Curve of Fluctuation of Attention. Brit. J. Psychol.*, 25, p. 221 (1934).

Another branch of experimental psychology busies itself with the physiological concomitants of emotional experience. On a smoked drum record of a subject's breathing, measurement can be made of frequency and amplitude, and changes therein can be compared with introspection records to find out their meaning. The inspiration-expiration ratio, with varying emotional states, shows marked variations from the average value, rising to as much as three times that value in ' amazement ' and sinking to about half the value under the sense of guilt or shame awakened by conscious misrepresentation or wilful falsehood. These changes in the ratio of inspiration to expiration are



Scale ½.

FIG. 4. TACHOGRAM RECORDS FROM

7. A Hopeless Dawn.....Frank Bramley, A.R.A.
8. Two Strings to her Bow.....John Pettie, R.A.
9. Renunciation.....P. H. Calderon, R.A.

accompanied by marked changes in frequency, amplitude and form, which result in characteristic curves that the eye can read and interpret without recourse to the millimetre scale and time record. The whole profile, rather than its analysis, is diagnostic.

A sensitive physiological concomitant brings about the fall in resistance that is commonly called the psychogalvanic reflex. In Fig. 4 we have curves traced by light from a mirror galvanometer on photographic paper as a record of the changes in the secondary current of a transformer, the primary coils of which were in a circuit in which current changes were occasioned by variations in the resistance of the subject's hand when looking at a series of pictures. It would be possible to convert the curves into electro-dynamic units of energy, but such refinement is unnecessary and, at present, would be of little practical value. The energy is proportional to the area enclosed between the curve and baseline and the relative values of its amount correspond with the relative values of the emotional-conational content of the experience. The changes in

outline correspond to introspected changes in experience and, with the subject who gave these records, differences in the shapes of the curves are diagnostic.

On the basis of such records it is possible to grade pictures in emotional value. Taking the records for a number of subjects and dividing the records into three grades it was found possible to break the pictures into seven groups, and selecting, from the centre of such groups, pictures that had a small scatter value we were able to secure a scale of values similar to scales which we shall see are playing a great part in more recent work. Instead, however, of resting wholly upon mental estimates our scale has the objective records of physiological changes as a basis.

An entirely different method of measurement had by 1920 reached the stage where it could not be ignored. Intelligence tests were being widely used, and the Board of Education set up a consultative committee to report ' on psychological tests of educable capacity and their possible use in the public system of education.' The Report appeared in 1924, and the principal findings of the committee were : ' That up to the present the only kinds of psychological tests of educable capacity that have been sufficiently developed to be of much service in schools for the purpose of diagnosing and assessing such capacity are tests of ' intelligence,' standardised scholastic tests, and to a less extent vocational tests.' [21] Let us consider the first of these.

In 1883 Galton [22] formulated the possibility of measuring intellectual abilities by laboratory tests. In 1890 Cattell [23] was writing on the subject and in 1896 he published the result of physical and mental measurements of the students of Columbia University.[24] In 1904 Spearman wrote on ' general intelligence objectively determined and measured,' [25] and in 1905 Binet published several articles on new methods of diagnosis of the intellectual level.[26] In the next fifteen years the measuring of intelligence by tests established itself in Europe and America.

The foundations of the method are laid in Binet's happy thought of ' mental age ' and Spearman's application of methods of correlation to psychological data. Prior to Binet's work testing had been confined almost entirely to tests of sensory discrimination. Spearman proceeded to calculate correlation coefficients between the results of such tests and estimates of intellectual ability. Binet ' instead of measuring the intensity of simple faculties ' set out by tests ' manifold and heterogeneous . . . (to) measure acts of adaptation . . . to determine how many years an individual is advanced or retarded.' [27] His measure is a time measure based on the normal development of intellectual ability. Originally his ' manifold and heterogeneous ' tests were 54 in number, used for the diagnosis of mental deficiency. This number has steadily increased until, in the New Revision of the Stanford-Binet Scale, issued by Terman and Merrill in 1937, there are two sets of 129 tests each, covering mental ages from 2 years to 22 years 10 months and providing for I.Q. values up to 170 for children and up to 152 for adults.

By correlation methods, Spearman compared the results of tests of sensory

[21] Board of Education, *Psychological Tests of Educable Capacity*, p. 136 (1924).
[22] *Enquiries into Human Faculty and its Development* (1883).
[23] *Mind*, XV, 9, p. 373 (1890).
[24] *Psychol. Rev.*, pp. 618–48 (1896).
[25] *Amer. J. Psychol.*, XV, 274 (1904).
[26] *L'Année Psych.*, 11, pp. 163–336 (1905).
[27] *Psychological Tests of Educable Capacity*, p. 24 f.

discrimination and estimates of intellectual ability, inaugurating a new phase of mathematical activity in psychology, in which, again, the tasks led to new methods. Often, when we lack a scale wherewith to measure, it is possible to arrange persons or things in order of merit. To deal with such 'rankings' of estimates, Spearman [28] transformed the Pearson-Bravais expression $\frac{\Sigma(xy)}{\sqrt{\Sigma(x^2)\ \Sigma(y^2)}}$, where x and y are deviations from mean values, into the expression $1 - \frac{6\Sigma(d^2)}{n(n^2-1)}$, where d is the difference in the ranks given to the individual for the two abilities or other characteristics.

The correlation between two sets of measurements or rankings is a measure of the extent to which the sets of figures agree, and this agreement would seem to be due to a common factor in the abilities measured. It follows that ' when any pair of abilities are to any extent correlated with each other, to this extent *they can be regarded as depending upon a common factor.* . . . Otherwise expressed, each of the abilities may be taken to involve two factors, the one common to both, the other specific to that ability alone.' [29] Extending this thought to more than two abilities, Spearman developed his theory of two factors, and evolved various criteria for establishing the existence of the relations that fit the theory, culminating with the tetrad equation, $r_{ap}r_{bq} - r_{bp}r_{aq} = 0$, and its probable error.

The final proof of this criterion rests upon Yule's formula for partial correlation, on which a word should be said. In psychological experiment, it is usually impossible to secure conditions free from all sources of variation other than those we wish to study. Partial correlation gives the means of eliminating the effects of disturbing influences by the calculation of what the correlation between two variables would have been if other variables had been constant.

The common factor of the two abilities becomes the ' general factor ' of the many. There emerged ' the concept of a hypothetical *general* and purely *quantitative* factor underlying all cognitive performances of every kind.' [30] This has been equated with ' general intelligence ' and labelled *g*. It is an innate capacity to acquire abilities to varying degrees. Its measured value enables children to be divided according to capacity to profit by education and adults according to the kinds of work for which they are fitted. Such a classification was given by Burt in his presidential address at Liverpool, in 1923.[31]

The method that gave *g* would equally well give other general or group factors if tests were found that gave correlations obeying the tetrad law and independent of *g*. Some of such factors are a general character-factor (*w*), perseveration (*p*), and oscillation (*o*), which were isolated by Webb, Wynn Jones and Flugel, respectively.

Soon, however, the difficulty of securing that freedom from ' overlap ' which is demanded by the Spearman technique led to the development of methods of analysing tables of correlations in which there are factors that are common to a number of the tests. These are the methods of Factor Analysis,

[28] *Amer. J. Psychol.*, XV, p. 274 (1904).
[29] Spearman, *Abilities of Man*, appendix, p. i (1927).
[30] Spearman, *The Nature of 'Intelligence,'* p. 5.
[31] *B.A.A.S. Report*, p. 227 (1923).

the exact value and meaning of which are still matter of debate. The record of a symposium of the British Psychological Society on the subject is appearing shortly in the Society's *Journal*.

In all this correlational work it is needful to know the reliability that can be placed on the data, whether obtained by measurement or estimate, and whether the correlations have significant value. Methods for dealing with these problems are available. Also a growing use is being made of Fisher's [32] development of Pearson's χ^2 test of significance, while an interesting development of the use of rankings is that of Kendall's [33] ' new measure of rank correlation.'

The 1924 Educable Capacity Report gave limited approval to vocational tests but concluded that ' the range of such tests (was) not yet sufficient for any recommendation.' [34] The Medical Research Council through the Industrial Fatigue Research Board had been busy with the problem for some years, and in 1922 this Board, in co-operation with the National Institute of Industrial Psychology, undertook a preliminary investigation into the possibilities of vocational guidance. The group of psychologists who, under the leadership of Prof. Burt, carried out the investigation reported in 1926.[35] The research had shown that both stability of employment and satisfaction are greater amongst those who had obtained employment in keeping with the recommendations made on the basis of the test results, than amongst those in other employment, and that it would seem true that the methods used ' will prove of the utmost value to the individual and to the community, to the employer and to industry as a whole.' [36]

More important, however, for our purpose, is that portion of Burt's conclusions which deals with the limitations of the tests. He wrote : ' It is clear that tests can cover no more than a limited part of the field. However perfect, however carefully standardised, tests by themselves mean nothing. To apply a scale of intelligence tests, and to read off the result in a single formula—a mental age or mental ratio—is but the beginning, never the end, of a vocational examination. . . . With almost every test and with almost every child, the real value of such method lies . . . in the interpretation of the test results . . . tests should be corroborated by personal observations ; many factors of the utmost importance in choosing a vocation are, in the present state of knowledge, not amenable to direct measurement by any of the tests hitherto devised. Of these additional factors, the most important appear to be qualities of temperament and character. Such qualities are more essential for industrial life than they are for progress in school work. It is, therefore, eminently desirable that suitable tests for such qualities should, if possible, be devised.' [37]

Since 1926 much work has been done on vocational guidance, both by the Board, under its new title of Industrial Health Research Board, and by the National Institute of Industrial Psychology. As a result of investigations carried out by these bodies and many individual research workers, in this and other countries, tests for abilities and skills of value in industry, and for particular disabilities that unfit for certain occupations, are available and are being used with increasing frequency. Much progress has also been made with the

[32] *Statistical Methods for Research Workers*, 7th Ed. (1938).
[33] *Biometrika*, XXX, I and II, pp. 81–93 (1938).
[34] P. 143.
[35] I.F.R.B. 33, *A Study in Vocational Guidance* (1926).
[36] Report 33, p. 102.
[37] Report 33, p. 100 f.

measurement of temperament and character, a valuable summary of which will be found in Report No. 83 of the Board.

In this report, Vernon reaches the conclusion that, while tests to measure attitudes or interests have not the objectivity and accuracy achieved by tests for abilities, and character and temperament traits present even greater difficulties, good progress has been made, and, with a better understanding of the methods and meaning of the results of factor analysis, ' we may hope before long to achieve a fairly complete classification of all our psychological measuring instruments which would be of the utmost value in many branches of pure and of applied psychology.' [38]

The order of progress has been : the measurement of intelligence ; the measurement of special abilities and skills ; the measurement of attitudes and interests ; the measurement of temperament and character traits. To deal with the growing complexity of the material, mathematical theory and technique have been developed until sometimes there seems danger of losing the facts in the figures, and it becomes necessary to remind ourselves that mathematical analysis cannot confer value on valueless data. The methods by which the data are collected are of prime importance. In the earliest work the instruments used were the ordinary scales of physical science ; what a man did or judged was submitted to measurement in millimetres, grams, foot candles, pitch, thousandths of a second, ohms. Physical measurement was possible, and, too often, was equated to the mental experience.

When physical measurement is impossible we may be able to secure rankings. Most people can arrange colours, pictures, persons, poems or holiday resorts in an order of preference. Consider the case of colour preferences. In sorting a set of fifty or more colours twice there will, as a rule, be considerable difference in rank of some of the colours, even if the second sorting be made immediately after the first. The greatest changes are with items towards the centre of the list, while the items nearest each end often retain their original ranks. Classification in rank presents greater difficulty with medium, than with extreme, values. To determine the value of the lists, we calculate the correlation between the two rankings. This gives the ' reliability ' (or ' consistency ') coefficient for the subject-task. From an important angle this coefficient is a measure of the reasonableness of the task.

Preference orders vary, sometimes greatly, from person to person. As a result we may find that, for a group of subjects, no item is consistently first or last. The variability of rank of the centre of the individual records has extended to the ends, and we may find, for sixteen colours, that the average rank of the colour most preferred is say, 3·6 and the least preferred, 11·9, while some colours have a very wide scatter value. If all the colours gave so high a scatter that it appeared that colour preference was completely specific, the average rank of each item would work out at a value equal to half the number of items. Thus the difference between the average ranks of the least preferred and most preferred is a measure of the magnitude of the common factor.

The rank order of the average ranks of the colours may be taken as a

[38] P. E. Vernon, *The Assessment of Psychological Qualities by Verbal Methods*, I.H.R.B. Report, No. 83, pp. 103–10 (1938).

norm of colour preference for the group. We can then calculate the correlation coefficient of any individual ranking with this norm and secure a measure of the normality of the particular subject. Of much greater interest, however, is the nature of the variations from the norm and any tendency there may be for subjects to fall into groups exhibiting similar variations. Determining the correlations between the various individual rankings, we can separate them into groups having high intercorrelations and then proceed to discover reasons for the agreements and differences. We may go further and, selecting groups in which the tetrad condition is satisfied, evaluate the amount of the common factor in each member of the group. The common factors of any two such groups will probably have something in common—a broad, more general, factor. Correlation of individual rankings with this more general factor will be lower than with the common factor of a group, and to that extent it is a measure of likeness to the common average rather than to the more valuable characteristic variation. Alternatively, we may submit the whole table of correlations to factor analysis and express each ranking as the sum of some four or five factors which may, or may not, have ascertainable meaning in relation to the subject's experience of the colours.

As the norms and the correlations rest on the rankings, it seems desirable that the rankings should be as accurate as possible and for that reason the method of paired comparisons was evolved. In this method, each item is compared with each other item. The preferred item in each comparison is credited with one mark, unless the items appear equal, when each is given half a mark. The order of preference is the order of marks obtained. The method is undoubtedly the best for determining the order of a few items, but when the number exceeds, say, twenty, it is best to make a rough ranking, or grading, first and then to take overlapping groups of, say, ten items and carry out the paired comparison technique on successive groups. It would seem, however, that for large numbers the method has little advantage over the rougher, ranking technique.

We have seen that the difficulty of securing consistent ranking at the central values is great. Often a subject will say it is impossible to distinguish any difference, and he accepts, with relief, permission to group together two or more of equal value. He is still happier if bidden to replace a ranking method by a grading one. Let him divide his material into a few groups that appear to him to represent equal steps of the quality he is judging and we can then evaluate the results by the Pearson-Bravais formula on the assumption that our grades are equivalent to measurements.

In 1926 [39] I reported to the Section a method of grading that had been evolved in dealing with the judgment of value of advertisements. In this ' method of fractionation ' groups are successively subdivided into three subgroups. To divide material into seven grades, we divide into three groups and number them 2, 4, 6, then divide each into three, numbering them 1-2-3, 3-4-5, 5-6-7. Coupling up the two threes and two fives, we obtain seven grades. If the material is a fair sample, taken at random, it will be found that there is a marked tendency towards binomial scatter. If we secure judgments on, say, the relative attention-catching power of a large number of advertisements from a number of judges we can cut our material up into

[39] *B.A.A.S. Report*, 1926, p. 401. *J. Nat. Inst. Ind. Psych.* III, 5, pp. 252–63 (1927).

seven or more groups. Then, selecting from each group specimens which are central for the group and have a small scatter value, we can build up a scale by which we can evaluate other advertisements. In this evaluation the judge is not asked to give his own opinion of the advertisement, he is asked simply to compare it with the scale.

In one case, four practised subjects compared 417 advertisements of a particular firm with a scale of seven grades, showing half grades, prepared from the whole of the advertisements in a week's issue of the *Daily Mail*. The averages of the four evaluations gave subdivision to eighths of a grade. Plotting the number of advertisements falling in grade blocks centring at each eighth

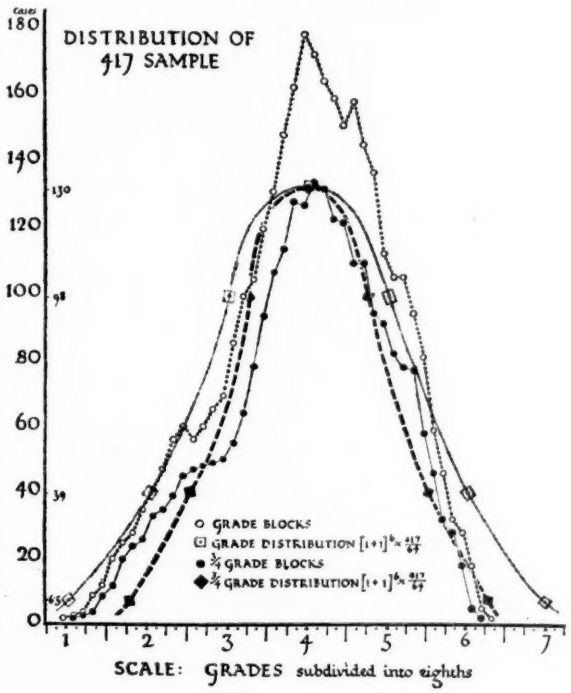


FIG. 5.

in the scatter a result was obtained as in Fig. 5. There is an approximation to binomial scatter. The material, however, is more homogeneous than that from which the scale was prepared and the curve rises above the binomial curve and shows a smaller scatter. Returning to the data and calculating the size of $\frac{3}{4}$ grade blocks a second curve is obtained. This gives a very close approximation to the binomial curve plotted on this smaller base.

A similar technique has been applied in the preparation of attitude scales such as Thurstone and Chave's *Attitude to the Church Scale*.[40] From 130 statements about the church, on the basis of the opinions of 300 judges who divided the material into 11 grades, 45 statements which had relatively small scatter values were selected. These 45 items, instead of being chosen, as in our

[40] *The Measurement of Attitude* (1929).

scales, to fall at the scale and half-scale numbers, were chosen without any reference to the actual scale values except that they should be spread fairly evenly over the entire range. Their median values, as 3·6, 7·1, were taken as their scale values. To use the scale, the person whose attitude towards the church we wish to measure is asked to check those statements with which he agrees, and the mean or median value of his range of choice is taken as the measure of his attitude. Our own experience confirms Ferguson's [41] conclusion that the large number of judges employed by Thurstone is unnecessary, as the personal attitude of the judges towards the statement influences the results little if at all. There is a very high agreement amongst judges of very different personal attitudes as to what is favourable or unfavourable to a particular thesis. Ferguson found that reliable values could be derived from the work of twenty-five judges.

We pass next from attitudes towards persons and things to the question of personality characteristics. Here, as a rule, the scale that we use is completely subjective, the judges' opinions of the extent to which the characteristic is present being expressed in some recordable form. The judge may decide that his own or another's ' adaptability ' is Poor, Fair, Good, Very Good or Excellent, and these classes may be turned into numbers 1 to 5. He may class a person as Schizophrene, Schizoid, Schizothyme, Neutral, Cyclothyme, Cycloid, Cyclophrene. He may rank persons by the usual techniques in order of merit or assess value by giving marks up to 10 or 20. He may approximate to an objective standard by the so-called ' Man to Man ' scales, in which two persons are selected as exhibiting the trait in extremely high and extremely low form, respectively. Then a person is chosen that falls half-way between the extremes and then two others half-way between the central person and the extremes. We have thus a scale of five reference values, secured by a method similar to the psycho-physical method of equal appearing intervals. In using such a scale we shall find that many of those we wish to judge fall between two of the scale values and, as with a transit instrument or other reading, we find ourselves estimating halves and quarters and, with increased practice, tenths. Or again, we may objectify the distance between the scale items as lines and mark the point on the line that corresponds to the position taken by the person in the mental scale. It will be remembered that at the York joint discussion Dr. Richardson used such a *Graphic Scale* to secure estimates of relation of a particular colour to two others by a method of *un*equal appearing intervals.

Instead of the five or more subjectively evenly placed grades, we may resort to the Thurstone technique and secure equivalent-unit rating scales of fifty or more items, each item being a statement that can be made about the characteristic, carefully selected and scoring its median grade. Somewhat similar are the Social Maturity scales, in which a number of statements about the common activities of children and adults are marked with the normal age of acquisition of the ability. By their use a Social Age and Social Quotient are secured in the same way as the Mental Age and Intelligence Quotient.[42]

When a number of characteristics have been rated they may be brought

[41] *J. Soc. Psych.*, 6, 115 (1935).

[42] K. M. B. Bridges, *Social and Emotional Development of the Pre-School Child* (1931). E. A. Doll, *The Vineland Social Maturity Scale* (1936).

together graphically in the form of a profile, and such profiles have been found of great value in vocational selection and guidance. Instead, however, of measuring a number of individual characteristics and then bringing them together in a profile we may rank or grade the various characteristics among themselves for a particular person, and compare that person with another by calculating the correlation between the rankings or gradings of their respective characteristics. Further, if we assume normal scatter and throw each individual set of traits into identically sized groups balanced about the central value, we can calculate the correlation by the very simple formula,

$$r = 1 - \frac{\Sigma\,(X - Y)^2}{K}$$

where X and Y are the actual grade values given to the various items and K a constant equal to half the possible maximum value of $\Sigma\,(X - Y)^2$. The method of correlating persons had been used for some years without its essential difference from correlation of tests being clearly stated. It is to the credit of Stephenson that in his papers on ' The Inverted Factor Technique ' [43] he has defined these differences and drawn attention to the advantages of the method.

We have sampled the methods and results of experimental psychology and trust that the sample is a fair one, though possibly somewhat overloaded with ancient history that has become of interest to physicists in contact with the human factor. The sample is statistically inadequate, but has, we hope, enabled the mind to perform its accustomed trick of reaching conclusions from cues or data logically and mathematically altogether insufficient. We have seen psychologists using physical measurements and developing methods of dealing with the new forms of data so obtained. We have seen them following intuitive perception in the belief that their material had quantitative elements not at present amenable to the measurements of the physicist, replacing the scales of physics by estimates, ranking, grading and rating scales and developing mathematics to deal with these new data. We have seen them progressing step by step into more and more difficult fields of inquiry, and may look forward with confidence to yet greater achievements. In these circumstances does it matter much if some continue to believe, with Malebranche, Leibniz and Kant, that our data contain nothing ' that can properly be called measurements ' and that it is presumption for us to think that, in any reasonable sense, our data, theories, methods and results constitute ' a systematic science ' ? After all there is a sense in which logical and mathematical proofs are what the psychology of advertising has called ' rationalisation copy.' Scientific insight, as everyday perception, has ever run ahead of measurement and mathematical proof.

[43] *Brit. J. Psychol.*, 26, 344 (1936) : *J. Ed. Psychol.*, 27, 353 (1936). *Brit. J. Psychol.*, 30, 19 (1939).

SECTION J.—PSYCHOLOGY

COMMUNICATIONS

Session on Films.

Mr. A. Mackay.—Films in schools.

Of all classroom aids to education the most forceful in its appeal to children is undoubtedly the cinema. The innate love of the child for the dynamic rather than the static was more completely satisfied when the still picture came to life. It is in the field of motion and activity that the cinema has its greatest educational value.

The widespread impression, that the viewing of motion pictures induces in children a habit of passive reception inimical to active thinking, has been proved erroneous by experimental work in this country and in the United States. In an American experiment, where a film group was tested against a non-film control group, the film group excelled the control group by a larger margin on the eduction items than on the rote items, and this result was even more pronounced in the retentivity tests. A notable conclusion drawn from many experiments is that in film-taught classes the relative gain of the lower intelligence groups is higher than that of the higher intelligence groups.

For children who, owing to social circumstances, lead lives of circumscribed experience, the cinema is indispensable, for it enriches experience by enabling pupils to view scenes and activities otherwise difficult or impossible to present in the classroom.

Dr. W. B. Inglis.—Children and entertainment films.

Changing techniques and content, variations from one country to another in laws governing censorship and the admission of children to cinemas, the lack of adequate psychological measurements of personality and temperament render it impossible to make valid generalisations concerning the effects of the entertainment film on children.

Three main methods have been used in investigating this topic. These are : (1) questionnaires dealing with such subjects as frequency of attendance at cinemas and film preferences ; (2) laboratory investigation exemplified in studies using the psycho-galvanometer and the hypnograph ; (3) the examination of cases in child guidance clinics. The results have been supplemented by the application of general psychological principles to the problems.

The relevance of the data thus obtained may be seen in discussing such topics of popular controversy as the relation between the cinema and anti-social conduct, the effects of terror films, the alleged failure to distinguish phantasy and reality resulting from frequent attendance at cinemas.

The vices of the entertainment film for children tend to be emphasised to the neglect of their virtues.

Mr. A. Cavalcanti.—Propaganda by films.

Entertainment films, which comprise the bulk of the films seen, are full of implicit propaganda in favour of riches, good luck, social and personal success. They present a picture of the world from which all reference to fundamental economic and political questions is deliberately omitted.

Newsreels present facts, but the emphasis is not on what is socially important, but on what is sensational or amusing or disturbing or impressive to the popular mind. In this they follow the press. Moreover the influence of the press introduces the element of political propaganda, which militates against the disinterested presentation of fact.

Propaganda films are, so far, a very small proportion of the total number of films produced. In the totalitarian countries films are made and shown in order to increase the prestige of the regime, and also for educational purposes. Large amounts of money are available for their production. In the democratic countries, the sums devoted to film propaganda are very small. In this country, most of the money is provided by commercial or industrial sponsors. Sponsorship imposes certain limitations, but it does not prevent good work being done. In spite of it, the individual film-worker remains to a considerable extent free to engage in social education.

Under democracy, the individual is permitted to consider and report facts around him with a free mind, emphasising what he feels to be most important. It is for this reason that democratic propaganda films are always stating social problems while totalitarian propaganda films are always staging parades.

Democratic people believe in the statement of truth for its own sake, holding this to be the first condition of good government.

Mr. Oliver Bell.—Public tastes and the entertainment film.

In forty years the film has developed from a fair ground side-show to a major industry catering for the entertainment of 220,000,000 of people in the world each week. The combined effect of the comfort of the cinema theatre, the psychological effect of looking at a brightened screen in a darkened theatre, the emotional rather than intellectual appeal of the films and the varying motives which lead patrons to pay to enter, dull film-goers' critical senses and render difficult the assessment of public taste. Furthermore, this immense industry has been built up by showmen and conforms to their standards. By unscientific intuitive methods they have roughly assessed public taste and made sufficient profits.

How little the producers really know of public taste is shown by the manner in which each financially successful film is followed by a spate of imitations. No determined effort seems to have been made to discover the psychological effects of the visual realism obtainable through no other medium, since the theatre is artificial and books are just words. The prime necessity of the moment is the creation of a Market Research Board working in co-operation with bodies like the Film Institute, reflecting the attitude of serious film-goers, and the relevant Government Departments and which will co-ordinate to their mutual advantage the conflicting viewpoints of producers, renters and exhibitors, and equate on a scientific basis the demands of the public with the financial, technical and artistic resources of the industry.

* * *

Mr. P. Smith.—Selection of skilled engineering workers.

Considerable research work has been undertaken to assess the value of psychological tests in giving vocational guidance to children leaving school. The Birmingham Education Committee has been closely associated with these investigations during the past twelve years, and has published four reports. One of the experiments was designed to investigate the possibility of using psychological tests in the selection of boys for apprenticeship to skilled engineering. This enquiry centred round a junior technical school to which boys are admitted at the age of about 13 plus for a two-year course. Evidence was obtained that aptitude tests applied to boys on admission were more prognostic of success in the school course than was the ordinary academic entrance examination.

The essential criterion of the value of the tests was the boys' success in engineering and allied occupations and the boys leaving the Technical School were ' followed-up ' in their industrial careers. It was found that success in the test battery was

more indicative of success in engineering and allied occupations than was success in the academic examination.

The recent publication of the Spens Report emphasises the need for improved methods of selecting boys fitted for admission to Technical High Schools. The Birmingham research work should be of great value to Local Education Authorities in this connection as well as of importance in the field of vocational guidance.

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Dr. N. A. B. Wilson.—A survey of a vocational adviser's case book.

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Miss Isabel J. Blain.—Analysis of industrial skill by motion study.

In an attempt to discover specifically what movements characterise skill in industrial assembly, film records were made of electric meter assemblers at work. These records showed performances in comparable pairs, as follows : (1) work of one operator on the same job at two stages in her learning process ; (2) work of two operators doing identical jobs, but having different degrees of efficiency.

Detailed analysis of the films in terms of therbligs (i.e. elements of movements required by industrial operations) revealed that certain movements were quicker in the better performances, while other movements occupied about the same time wherever they occurred. ' Assembling ' movements exemplify the former class, and ' transporting,' ' grasping ' and ' positioning ' the latter. ' Using ' actually occupied a higher proportion of total time in instances of greater skill. There tended to be fewer therbligs in the more skilled examples of performance. ' Positioning,' ' assembling,' ' using,' ' holding ' and ' transporting,' where they occurred at all in an operation, each generally occupied from 20 to 35 per cent. of the total time required for that operation.

Observation of the finer characteristics of different kinds of movements gave rise to certain tentative conclusions regarding the effects of experience and training, and suggested guides for future practice. ' Holding,' for example, proved less passive than has been supposed, and the theoretical perfection of absolutely symmetrical and simultaneous movements may be questioned. There was some indication that the most significant characteristics of skill do not all lie in the grosser motor components, but some, probably, in cognitive and kinæsthetic elements.

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Miss M. M. Mellis.—A study of the sorting process in laundries.

General description of what is involved in this operation, which is the starting-point of the laundry processes within the factory. The various checking and identification systems commonly used in the industry.

Summary of the results of time-studies of the sorting process. How these show the predominating elements of the work and certain technical features. Sorting is seen to be rather different from ordinary industrial operations in that the requirements for successful work are mainly mental ones, such as good powers of attention and discrimination.

Discussion of individual difference in sorting efficiency and their consequent bearing on selection tests, training, control and incentives.

Tests for sorters—how they were devised and how they can be used.

* * *

Prof. K. Koffka.—The ego in his world.

Human behaviour is action of a person in a world. We can understand it only if we understand the Ego-environment relationship. To illuminate this relationship

different types of behaviour will be compared : our own with that of more primitive peoples and of patients with brain injuries. The behaviour of the two last classes, though by no means identical, presents several similar features, like concreteness and lack of spontaneity, which throw light on our own behaviour.

Psychology can accept neither the Ego nor its environment as unexplainable ultimates. The attempt must be made to understand both as creations of the organism. In such a theory Ego and environment develop in close interdependence, and the different types of behaviour previously discussed appear as the outcome of different forms of Ego-environment organisation, different with regard to the Ego, the environment, and the relation between them ; such different forms of organisation must lead to characteristically different forms of action.

* * *

Prof. J. Murphy.—The primitive character of poetic genius.

The salient characteristic of all genius is imagination ; and it is particularly the quality of poetic genius. Imagination is a more primitive power of the mind than, say, the capacity for abstract or conceptual thought. The poet precedes the philosopher in history, as the primitive and tribal mind comes before the civilised. The primitive mind is ' perceptual rather than conceptual ' ; hence words which were images from perception and from the concrete preceded abstract terms, and primitive language is highly metaphorical. The earliest literature is poetry. We note the poet's use of image and metaphor in modern times, his delight in wild nature, his ' poetic observation.' The child, the poet and the primitive.

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Dr. P. E. Vernon.—Predicting the psychological aptitude of university and training college students.

The marks of over one thousand students in psychology, and in other subjects studied at a training college for teachers, were compared with scores on intelligence, and other mental tests. Factor analysis of the marks gives clear evidence of a general educational ability factor (which is largely independent of the *g* measured by intelligence tests), and additional group or multiple factors of scientific ability, literary-humanistic ability, and practical ability. Non-verbal group tests give moderate correlations with scientific ability, verbal tests with literary ability ; neither correlate appreciably with practical ability. Psychology marks are best predicted by a combination of the two types of test. With one group of students a correlation of $+ 0{\cdot}535 \pm 0{\cdot}032$ was obtained.

Promising results were also obtained with tests of adult reading ability, with certain educational tests such as scientific vocabulary, and with personality and interest questionnaires. The ' good ' psychologist seems to possess a distinctive pattern of interests and personality traits. On the basis of these results it is suggested that a battery of aptitude tests for psychology students might be devised which would be of considerable practical value.

* * *

Dr. W. Stephenson.—The psychological respectability of physical activity.

There is to-day a widespread interest in physical education and training—the whole nation has been appealed to and enjoined to become ' keep-fit conscious.' Most people would admit the importance of maintaining a certain minimum, at least, of physical fitness ; but the general public is perhaps insufficiently educated about the effects of bodily fitness upon mental condition, and psychologists have as yet given little attention to these effects. The present paper offers a brief review of the present state of our knowledge on this matter of the psychological effects of

bodily fitness. The corrective methods of F. Matthias Alexander are considered as an example, and some experiments on posture are described. The suggestion is made that physical activity would be more seriously regarded if more attention were given to it by experimental psychologists, who should provide the general public, and physical training experts, with a general theory upon which to base their thoughts and work on physical education.

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Mr. W. H. N. Hotopf.—Some relations between characteristic interests of schoolboys.

About 500 boys between the ages of 11 and 16, mostly from elementary schools, were questioned in interviews lasting from 15 to 20 minutes about their interests and hobbies. The relations between these interests and the boys' test scores for intelligence and mechanical aptitude were examined. The interests of the boys were considered also from the point of view of temperamental qualities and general attitude and, where possible, the results were applied for the purpose of vocational guidance. The results were further examined for any light they might throw upon the question of changes of interest with age.

* * *

Mr. H. McRae.—Reliability of group intelligence tests.

Previous work with intelligence tests has indicated that the reliability of the test results is greatly impaired by the fact that individuals vary from week to week in their power to perform such tests. A special experiment was undertaken to investigate this individual variation.

About fifty pupils, tested individually about eight months previously, were given a series of six group tests of intelligence at weekly intervals. The resulting I.Q.s were worked out for each test. Due allowance was made for the fact that the median score and ' scatter ' varied from test to test, before the I.Q.s were finally compared.

Such a comparison constitutes the main part of this paper.

Apart from verifying that the tests used are not standardised on the same basis and that there is a definite practice effect over a series of tests given at weekly intervals, this investigation shows that individual variation (of more than twenty points in some cases) does exist, although it is suppressed and hidden in all work where the conclusions are based upon ' average results.'

* * *

Dr. E. A. Bennet.—Methodology in psychological medicine.

The classification of observations made in the course of clinical practice in psychological medicine is necessary if knowledge is to increase. Owing to the circumstance that our reflections proceed along different ways, we do not fix our attention upon the same objects. One will note the behaviour of a patient, another his physique, while a third notes only the working of the patient's mind. These three approaches may be loosely coupled together ; and one or other may receive special attention. When the third—the working of the mind—is included it involves the observation of mental activity both in consciousness and in the unconscious. It becomes necessary to employ a method suitable to this field. In such subjects as the science of history and the practice of psychotherapy events cannot be repeated. They belong to a certain time. Furthermore the personality of the psychotherapist is necessarily involved in the psychotherapeutic discipline. The value of the scientific method is so great that there is a desire in some quarters to universalise its application. An absence of subjective elements, observations tested

by experiment and capable of being repeated by another, are features of the scientific method. It is contended that this method is only partially applicable in psychotherapy. A method must therefore be used which will reveal the psyche and particularly the unconscious factors therein. As in physics so in psychology, a personal element enters. The method most appropriate at the present stage of our knowledge must include the recognition of individualistic as well as general elements. It is contended that such a method can be formulated ; and that by its use the material with which psychologists have to deal is made available and can be studied systematically. The use of individual material in a subjective manner is permissible if thereby we come to understand that the material is not only subjective—it is also objective ; and as such is subject to general considerations.

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Dr. M. M. Lewis.—Recent developments in the psychology of language.

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Dr. S. F. Nadel.—New field experiments on racial psychology.

The experiments described in this paper represent a combined psychological and anthropological effort. They were carried out in Nigeria in 1936, with subjects taken from two large tribes, the *Nupe* and the *Yoruba*. The aim of the experiments was to ascertain the extent to which differences in culture and race may affect psychological responses and dispositions. In each group a series of six different experiments was carried out, some of which—experiments on memory—have been published already (*British Journal of Psychology*, 28, 1937). The present experiments used verbal material, and were devoted to the examination of certain thought processes, namely, the formation of abstract concepts and of logical categories (e.g., opposites, cause-and-effect, etc.). The experiments reveal a marked divergence in the responses of the two groups, which can be correlated with cultural differences. As these thought experiments use material closely akin to that used in certain intelligence tests, the results are significant also with regard to the controversial question of inter-racial, viz. inter-cultural, intelligence testing. The divergence in the responses obtained from the two groups reveals the presence of specific qualitative factors in intelligence which do not lend themselves readily to quantitative comparison.

* * *

Dr. B. Semeonoff.—Common sense in music testing.

The main purpose of the investigation described was to devise tests of native musical ability, using material of a truly musical character. Many of the existing tests measure sensory discrimination, etc., which, though no doubt positively correlated with musical ability, present a test situation totally unlike the experience of making or listening to music.

Tests of a creative character were set aside for the time being, chiefly because the activity involved was felt to be strongly influenced by teaching—though the difficulty of separating innate from acquired musical ability became increasingly apparent. The tests used were partly based on the work of previous investigators, but with sufficient difference to be considered original. They comprised tests of musical knowledge, of interpretative ability and of musical taste. It is hoped later to add a test on the appreciation of musical form. The first of these consisted of a questionnaire, and the results were valuable chiefly as an indication of the ' musical status ' of the individual. The other tests were based on the responses obtained on listening to gramophone records, the selections being, as far as possible, of relatively unfamiliar music. Different forms of the tests were applied to secondary school

children of about eleven to fifteen years of age, and to university students in the faculties of Arts and Music.

It is suggested that teachers and others interested may adapt the test material and method to their own requirements, since accurate standardisation seems neither possible nor altogether necessary.

* * *

Discussion on Training the mind.

Mr. Rex Knight

Training the mind, as distinct from stocking it with facts, is often neglected, because, as Dr. Mace has said (*The Psychology of Study*, p. vi) ' in our ordinary educational system, whatever is not a special " subject " is the business of no one in particular ; and training the mind is not a subject.' It used to be thought that mental training is secured merely by learning Latin, or Euclid, or some other such subject. But experiments, to which Mr. Hardie will refer, have shown that transfer of training is often lacking and always limited.

What is needed is express instruction and training in, *inter alia*, (i) the essentials of accurate and serviceable observation ; (ii) the best ways of improving the memory ; (iii) the technique of silent reading ; and (iv) the psychology of clear, logical thinking. These being trained should also be shown the other side of the picture—the errors of observation and memory and reasoning to which the mind is especially prone.

All this should be done in a concrete, realistic way. For example, in dealing with the non-rational methods by which people mislead themselves or are misled by others, the training must be useful and practical, like that set forth in Dr. Thouless's *Straight and Crooked Thinking*, and must also take full account of the great influence of emotional factors, which Dr. Mace will discuss.

Mr. J. L. Hardie

The nomenclature is misleading. It suggests the recrudescence of a belief, once piously held, that the mind is not so much a receptacle for facts but an instrument for dealing with facts, and that the teacher's primary concern is with the faculties of the mind rather than the medium in which the mind works. The essential problem may be stated thus : To what extent and under what conditions does the effect of training in one subject transfer to other subjects ? The results of experimental investigation indicate that the conscious application of ideals, principles, attitudes and methods produces some degree of transfer, while uninstructed or unintelligent practice does so only to a negligible extent, or not at all. But the orectic factors have not yet been adequately taken into account. The criterion for the inclusion of a subject in the curriculum should therefore depend not upon its value as a mental discipline, but upon its social utility. Two factors that militate against transfer are the lack of correlation in the curriculum, and the baneful influence of examinations. The effect of intelligence on the degree and the amount of transfer is not yet clear, but the assumption that the possibility of transfer is greater in children than in adults seems *a priori* reasonable.

Dr. C. A. Mace.

The problems defined by Mr. Knight, Mr. Hardie, and Dr. Thouless are urgent educational problems, but they are not purely educational ; since some of the chief influences upon habits of thought reside within the wider social background by which educational principles and policies are themselves conditioned. It is not

enough to cultivate the capacity for straight, clear, and accurate thinking; it is essential *to foster and maintain the will to think to good effect.* The problem of transfer is not one of the transference of acquired skills but of the transference of motives and attitudes. The development of appropriate attitudes is hindered within the school by factors such as those to which Mr. Hardie refers (curricula and examinations), but even when present in the treatment of school subjects the transference of these attitudes to extra-scholastic fields is made difficult by the social conditions which limit the utility of even the best of 'academic' intellectual attitudes when applied to 'practical' affairs. The psychologist interested in the 'functions' which processes subserve will take notice of the fact that there are situations in which bad thinking succeeds where good thinking fails.

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Dr. H. L. Philp.—An experimental approach to the psychology of frustration.

Reports were made on different aspects of frustration as made manifest in the solving of puzzles. Pneumographic and psychogalvanic records were taken, while intelligence tests were given for control purposes.

The research indicated the general phenomenology of frustration to be (*a*) a confused experience of conative effort together with (*b*) increased emotional experience composed of negative self-feeling, disappointment, disgust, anger, etc. Light was also thrown on the causes of frustration, some being due to the blocking of biological goals, while others were connected with aims more consciously determined.

Among the conclusions were the following: (*a*) Conative activity when blocked tends to be changed into intense emotional experience, (*b*) the feeling tone of frustration is relatively fixed, while (*c*) there is possibly a quantitative principle of emotionality, this last-named having an important bearing on practical life as, e.g., in examinations of all kinds, or in one's power to work smoothly and effectively. Freedom from this type of emotionality has been expressed as a high degree of frustration tolerance. Incidental conclusions revealed that there are no correlations of any significance between puzzle-solving ability on the one hand and intelligence or perseveration on the other.

* * *

Dr. S. Rosenzweig.—Need-Persistive and Ego-Defensive Reactions to Frustration.

Types of reaction to frustration are divisible into those which serve to fulfil the frustrated need in spite of the obstructions occasioning frustration and those which serve to protect the inviolacy of the ego should the latter be threatened by the frustration. The former type of reaction is regarded as occurring invariably after frustration, whereas the latter occurs only under special conditions of ego-threat. Most behaviour following upon frustration involves both types of reaction, but pure cases of each are found and the theoretical distinction aids analysis.

An experimental study of memory offers an experimental demonstration of the distinction. *Unfinished* tasks are better remembered than *finished* ones when all tasks are performed in an informal setting. This result is consistent with the findings of Zeigarnik and Lewin. By contrast, *unsuccessful* tasks are less well remembered than *successful* ones when all tasks are performed in a formal test atmosphere which evokes excitement and pride and thus potentially threatens the ego. While the former set of conditions elicits need-persistive reactions in recall, the latter elicits ego-defensive ones.

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Dr. J. Hettinger.—The ultra-perceptive faculty.

It has been alleged that by concentrating on an object a ' sensitive ' is able to cognise items concerning its owner, generally miles away. An extensive experimental investigation of this process, referred to in Psychical Research by the misnomer of ' psychometry,' was carried out at King's College, London. Various ' control ' methods were used and the results were statistically significant.

There followed a series of ' time factor ' experiments. Recent events, including the actual time of the experiment, were found to constitute a large proportion of the items accurately cognised. This seems to indicate that the psychological make-up of the owner of the object at the time of the test may possibly be the source of supply of the items perceived.

The inference just referred to led to a new method of investigation, according to which the sensitive ' psychometrises ' the object while its owner, miles away, peruses an illustrated paper. Time records kept at both ends show numerous instances of complete correspondence between the pictures and the items perceived ; also distortions, the reason for which is easily discernible ; and various other examples of thought-provoking relationships. These are illustrated by means of exhibits and lantern slides.

THE ATMOSPHERES OF THE PLANETS

By Dr. H. SPENCER JONES, F.R.S.

Being the Fourteenth Annual Norman Lockyer Lecture, delivered on December 6, 1938, in the Hall of the Goldsmiths' Company, London.

During the last few decades the main interests of astronomical research have shifted rapidly from the solar system outwards. The application of the spectroscope to the study of the stars and nebulæ, the use of photography, facilitating the study of faint objects, shortening the time of observation at the telescope, and providing permanent records, and the construction of larger and larger telescopes have made it possible for the astronomer to study objects at greater and greater distances. Whole new fields of research have been opened up, and the exploration of these has proved so attractive and has been so productive of results that the planets of the solar system have received much less attention than was formerly given to them. Nevertheless, the planets have not been entirely neglected in recent research. The great light-gathering power of large modern telescopes has enabled spectrographs of very high dispersion to be used for the more detailed study of the spectra of the planets, and the great advances in the manufacture of plates sensitive to the infra-red region of the spectrum have made possible the investigation of a region of the spectrum whose importance arises from the fact that the selective absorptions by planetary atmospheres lie mainly in this region. It is my purpose this afternoon to summarise some of the conclusions about the physical conditions on the planets derived from the investigations of recent years.

From theoretical considerations it is possible to decide whether or not any

planet may be expected to possess an atmosphere. The natural tendency of an atmosphere is to diffuse away into space. The molecules of the atmosphere are flying about in all directions at high speeds, continually colliding with one another and rebounding. In the upper layers of the atmosphere, the preponderant tendency is for them to be pushed outwards. They are prevented from escaping only by the gravitational pull of the planet.

In order to overcome this pull and to fly away into space, any particle, whether large or small, must acquire a velocity greater than a certain minimum value, determined by the mass and radius of the planet. If the radial component of the outward velocity is greater than this minimum value, the particle will escape from the planet, provided its motion is not impeded by collision with another particle.

In a simple gas, at a uniform temperature, the velocities of the molecules are distributed according to a law, discovered by Maxwell, which he first announced at the meeting of the British Association in 1859. The mean velocity of the molecules increases with the temperature, being proportional to $\sqrt{T}$; the number of fast-moving molecules with velocities much in excess of the mean velocity falls off very rapidly with increase of velocity. In a mixture of gases, the average energy of each type of molecule is the same ; the lighter the molecules the faster they move in the mean.

There are definite proportions of molecules with speeds of 10, 20 or 100 times the mean speed, so that there must be a progressive loss of fast moving molecules from the upper layers of the atmosphere of any planet. The rate at which this loss takes place depends upon the relative magnitudes of the velocity of escape and of the mean velocity of the molecules. The rates of escape were calculated by Jeans. He found that if the velocity of escape is four times the mean molecular velocity, the atmosphere would be practically completely lost in fifty thousand years ; if the velocity of escape is four and a half times the mean molecular velocity, the atmosphere would be lost in thirty million years ; whilst if the velocity of escape is five times the mean molecular velocity, twenty-five thousand million years would be required for the loss to be almost complete. The age of the planets is believed to be of the order of three or four thousand million years, so that if the velocity of escape is as great as five times the mean molecular velocity of hydrogen the atmosphere will be practically immune from loss.

The mean molecular velocity of hydrogen at 0° C. is 1·84 km./sec. At the observed maximum temperature of the Moon, 120° C., it is 2·21 km./sec. The escape velocity from the Moon is only 2·4 km./sec., so that an atmosphere of hydrogen would be lost from the Moon almost instantly. Similarly for Mercury ; the temperature of the sunlit face is found by measurement to be about 400° C. and at this temperature the mean molecular velocity of hydrogen is 2·9 km./sec., whilst the escape velocity from Mercury is 3·6 km./sec. ; a hydrogen atmosphere would again be lost almost instantly. It appears that the Moon, if it had never been hotter than at present, would have lost water vapour, nitrogen, and oxygen completely, but would have retained carbon dioxide and heavier gases ; Mercury, under the same supposition, would have lost almost all its water vapour and nitrogen and most of its oxygen, but would have retained heavier gases to a large extent. The rates of loss are likely to be underestimated because, as we shall see later, it is probable that when these

bodies were young and had temperatures much higher than they now have, the loss of atmosphere during the period of rapid cooling must have been considerable. It is certain that the Moon has no atmosphere now and this is fully in accordance with expectations. The evidence of an atmosphere on Mercury is not fully conclusive, but faint and transient shadings on the planet have been interpreted by Antoniadi as indications of an atmosphere. The observations are naturally difficult, but the conclusion of Antoniadi that Mercury may possess a very tenuous atmosphere is not in conflict with the theoretical evidence. It is certain, however, that most of the original atmosphere must have been lost.

Coming to the Earth, the escape velocity is 11·2 km./sec., which is almost exactly six times the mean molecular velocity of hydrogen at 0° C. Hence the atmosphere of the Earth should be immune from loss of hydrogen and all other gases.

At the present time the amounts of hydrogen and of helium in the Earth's atmosphere are very small. The spectrum of the aurora does not contain the lines of helium, an indication that the high regions of the atmosphere cannot contain very much helium. The total helium content of the atmosphere has been estimated to be about five parts in a million. The supply is being gradually replenished by the weathering of the igneous rocks of the earth's crust, which contain uranium and thorium and also, consequently, helium. Yet the atmosphere does not now contain more than a fraction of the amount of helium that it has gained in geological times in the process of the formation of sedimentary rocks as a result of the weathering of the igneous rocks. We may therefore say that there is direct observational evidence that helium is being lost from the atmosphere at the present time. It is believed that there may be a state of equilibrium between the rate of supply and the rate of loss.

Even if the Earth had remained hot, in the early stages of its existence, for a sufficient time for the hydrogen and helium then present in its atmosphere to escape entirely, it still remains to explain how helium continues to be lost when, according to the theoretical results, which are based on the accepted principles of the kinetic theory of gases, it should be immune from loss. There is one process by which the escape of helium can be brought about. It is well known that the night sky is faintly luminous. In addition to the light from the stars there is a faint luminiscence from the upper atmosphere, whose brightness seems to vary with the sun-spot cycle, being greater at sun-spot maximum than at sun-spot minimum. Lord Rayleigh has termed this the non-polar aurora. In the spectrum of the night sky the characteristic green auroral line, as well as the two red lines, are always present. These lines are emitted by oxygen atoms that are in what the physicists term a metastable state. An atom, when excited or loaded up with energy, usually unloads its energy, with the emission of radiation, within a short interval of time of the order of one hundred-millionth of a second. But a metastable state is characterised by the peculiarity that the atoms in that state have a very slight tendency to unload their energy. They may remain for an average time of a second or longer in that state before emitting their energy in the form of radiation. There is a high probability that before this occurs the atom will have collided with another atom. When a collision of a metastable oxygen atom with another atom occurs, the energy of the oxygen atom will be unloaded and converted into kinetic energy. The

two atoms will rebound with a greatly increased speed. By such a collision an atom of helium could acquire a speed of more than 12 km./sec., which is greater than the velocity of escape from the Earth. Hydrogen atoms would acquire a still higher speed, but heavier atoms, such as those of nitrogen or oxygen, would not by this process acquire sufficient speed to escape. They would receive an equal amount of energy but, being heavier, they would not move so fast. The loss of hydrogen and helium from the atmosphere of the Earth is thus made possible by the fact that free oxygen is present in the atmosphere.

It appears probable that the primitive Earth must have remained hot sufficiently long for most of its initial atmosphere to have been lost. It was pointed out by Russell and Menzel that in the stars and the nebulæ neon is as abundant as argon, whereas in the Earth's atmosphere argon is five hundred times more abundant than neon. Nitrogen is far less abundant on the Earth than in the stars ; it is ten thousand times more abundant in the Sun than on the Earth. These large differences in relative terrestrial and solar abundance demand explanation, because in general the relative abundance of elements on the Earth is in close agreement with their relative abundance in the Sun and other stars. These facts can be accounted for on the supposition that the rate of loss of atmosphere was very rapid when the Earth was hot. When the cooling had proceeded sufficiently far for the escape of the atmosphere to cease, neon had been depleted to a much greater extent than the heavier argon. If this supposition is correct, much of the original oxygen, nitrogen, and water-vapour and all the original helium and free hydrogen must have been lost. As the molten Earth cooled, great quantities of water-vapour, carbon dioxide and other gases must have been evolved from the solidifying magma ; these, with the residual gases from the initial atmosphere, formed the new atmosphere which, as the Earth was then relatively cool, could not escape.

It has been recognised for more than a century that the presence of free oxygen in the atmosphere of the Earth, which we are apt to take for granted without a thought, needs explanation. Oxygen is an element that is chemically active and processes are in continual operation that are depleting the store of oxygen in the atmosphere. One of the principal sources of depletion arises from the weathering of the igneous rocks to form sedimentary deposits—sand, clay and mud. The iron contained in the igneous rocks is not completely oxidised. The greyish hue of these rocks results from the iron being present mainly in the form of ferrous oxide. During the process of weathering, much of the ferrous oxide is oxidised into ferric oxide, which gives the red or brown tints to the weathered deposits. The amount of oxygen that is withdrawn from the atmosphere by this process is very considerable and it has been estimated that during geological times the amount of oxygen thus depleted from the atmosphere is about twice the quantity now present. It is clear that some process must be in operation which replenishes the oxygen in the atmosphere. The vegetation over the Earth's surface provides the means for this replenishment. The green plant absorbs carbon dioxide from the air and uses energy from sunlight to decompose it, the energy-transformer being the green colouring matter, called chlorophyll, contained in the plant cells. The carbon is used to build up the complex organic substances found in living plants, the oxygen being returned to the atmosphere as a by-product.

The supply of carbon dioxide is in turn renewed by the decay of vegetable matter and other organic materials. During the decay of such matter, oxygen is absorbed and carbon dioxide is liberated. This carbon dioxide is again available for building up new plant cells. Whenever organic matter is buried, as in coal measures and oil deposits, so that it cannot become oxidised and decay, there is a net gain of oxygen to the atmosphere. It seems probable that the present abundance of oxygen in the atmosphere has been provided in this way and that if the coal, oil and other organic deposits could be unburied and completely burned, the whole of the oxygen in the atmosphere would be used up.

The atmosphere of Venus is in marked contrast to that of the Earth. Venus is the planet which, of all the planets, most closely resembles the Earth in size, in mass, and in mean density. It is a little smaller than the Earth, a little less massive and has a slightly lower mean density. The velocity of escape from Venus is 10·2 km./sec., a little smaller than the corresponding velocity from the Earth. This velocity is about five times the mean molecular velocity of hydrogen, and it may therefore be expected that Venus will have an atmosphere, comparable with that of the Earth in extent and density. The presence of an extensive atmosphere is confirmed by observation. Her disk shows faint ill-defined transient markings, which are evidently cloud phenomena. No surface details are shown, even on photographs with infra-red sensitive plates. Photographs in ultra-violet light record cloudy markings which rapidly change their form and are of short duration.

The permanent cloud layer over Venus makes the determination of the period of rotation difficult ; the cloud formations are not sufficiently long-lived to give any more definite information than that the rotation is not rapid. The spectroscopic determination of the period is difficult, but the evidence is in favour of a period of not less than 20 or 30 days. On the other hand, it is likely that the period is considerably shorter than 225 days, the period of revolution of Venus round the Sun, because it has been found by measurement that considerable heat is radiated from the dark side of the planet. Although the measurements show that the bright side sends us more heat than the dark side, the difference can be to a large extent explained by the reflection of sunlight from the cloud layer over the bright side. The small difference in temperature between the bright and dark sides is to be expected on a planet that is densely cloud-covered, the clouds acting as a blanket at night, provided that the length of the day is not too great. If the planet turned always the same face to the Sun, the difference in temperature between the bright and dark faces would be greater than is found by observation. Hence a rotation-period of several weeks seems probable.

The method used for the determination of the temperatures of the planets may be briefly described. The radiation received from the planet, or from a portion of its surface, is measured with a sensitive thermo-couple or bolometer. This radiation consists of two portions: reflected sunlight and long wave-length infra-red radiation from the planet. By placing a small transparent vessel containing water in the path of the rays the true planetary radiation of long wave-length is absorbed and the amount of the radiation that is merely reflected sunlight can be determined. Knowing, in this way, the amount of the true planetary radiation, the temperature of the planet may be estimated

approximately ; this temperature refers to the radiating surface, and if the planet has much atmosphere the actual surface temperature may be considerably higher.

The measured mean temperatures of the planets are in close general agreement with the temperatures calculated on the assumption that for each planet there is a balance between the radiation received from the Sun and the radiation re-emitted into space. The temperature differences from one part of the surface to another depend very much, however, upon the extent and nature of the atmosphere. A dense atmosphere greatly reduces the variations of temperature across the surface and the range of temperature between day and night. The Moon provides an extreme example of rapid variations. At the lunar eclipse of January 14, 1927, Pettit and Nicholson found that the temperature of the surface dropped from + 70° C. to — 80° C. in a little more than an hour, as the result of the radiation from the Sun being cut off by the interposition of the Earth. During $2\frac{1}{2}$ hours of totality, the temperature dropped a further 40° C. But after totality had ended, the temperature rose to almost its initial value in about an hour. Venus, on the other hand, despite its long day, shows only a moderate range of temperature.

To determine the composition of the atmosphere of Venus, or of any other planet, recourse must be had to the spectroscope. Absorption in the atmosphere of the Earth is a complicating and troublesome factor. Ozone, though present in the Earth's atmosphere in very small amount, with an equivalent thickness of but a few millimetres, completely cuts off the whole spectrum below λ 2900, so that the extreme ultra-violet region is completely inaccessible to observation. Oxygen reveals itself by some strong absorptions in the near infra-red and red regions, including the A and B bands of Fraunhofer and some weaker absorptions in the visible spectrum. Water-vapour has some extremely strong absorptions in the infra-red. The terrestrial origin of these various absorptions can be established in two ways. Firstly, by observing the spectrum of the Sun at different altitudes, the terrestrial absorptions become stronger the lower the altitude, because the air-path is correspondingly increased. Secondly, if the spectra of light from the east and west limbs of the Sun are compared, the absorptions of solar origin show a slight relative displacement caused by the solar rotation, whilst the absorptions of terrestrial origin are undisplaced.

The absorptions of terrestrial origin in the spectrum of the Sun having been identified, the absorptions produced in the atmosphere of a planet can be investigated by photographing the spectra of the planet and the Moon on the same night and at the same altitude. An absorption present in the spectrum of the planet and not in that of the Moon, or much stronger in the spectrum of the planet than in that of the Moon, must originate in the atmosphere of the planet. Another, and more delicate, method of investigation is to photograph the spectrum of the planet at a time when it is approaching or receding from us most rapidly. The motion will displace the absorptions due to the planet's atmosphere with respect to those due to our own atmosphere, and in this way the planetary absorptions may be revealed.

Complete information about the constitution of any planetary atmosphere is not obtainable, however, because many possible constituents of the atmosphere show no absorptions in the region accessible to study. Amongst such undetectable constituents are hydrogen, nitrogen, helium, neon and argon.

The investigation of the atmosphere of Venus has given no certain evidence of the presence of oxygen. Observations with the 100-inch telescope, in conjunction with the high-dispersion coudé spectrograph, have led to the conclusion that the amount of oxygen must be less than one-thousandth part of that above an equal area of the Earth. It must be remembered, however, that the observations refer only to the portion of the atmosphere above the permanent layer of cloud and this layer may be at a considerable height above the surface of Venus. More surprising, perhaps, than the failure to detect oxygen is the failure to detect the presence of water-vapour, even though the tests for water-vapour are less sensitive than those for oxygen. It would seem that the clouds on Venus must be clouds of water droplets, similar to the clouds in the Earth's atmosphere ; the explanation if the apparent absence of water-vapour may be that the atmosphere above the clouds is extremely dry.

The most interesting fact about the atmosphere of Venus is the great abundance of carbon dioxide. In 1932 Adams and Dunham discovered three well-defined bands in the infra-red region of the spectrum of Venus which are not found in the spectrum of the Sun, even when setting. They were evidently produced by absorption in the atmosphere of Venus. These bands had not at that time been observed in any terrestrial spectrum. Theoretical investigations indicated that they might be due to carbon dioxide ; this was confirmed when Dunham succeeded in obtaining a faint absorption, corresponding with the strongest of the bands, by passing light through 40 metres of carbon dioxide at a pressure of 10 atmospheres. Later, Adel and Slipher reproduced the three bands by passing light through 45 metres of carbon dioxide at a pressure of 47 atmospheres ; the absorptions so produced were less intense than the corresponding absorptions in the spectrum of Venus. Adel and Slipher concluded that the amount of carbon dioxide above the surface of Venus is equivalent to a layer two miles in thickness at standard atmospheric pressure and temperature. For comparison, it may be mentioned that the whole atmosphere of the Earth is equivalent to a thickness of five miles at standard pressure and temperature and that the amount of carbon dioxide present in the path of sunlight, when the Sun is setting, is equivalent to a thickness of only about thirty feet. Further confirmation is thus obtained of an abundant atmosphere on Venus.

The carbon dioxide will have a powerful blanketing effect, the escape of the long wave-length radiations being greatly impeded by the absorption by the carbon dioxide. It is not improbable that the temperature at the surface of Venus may be as high as, or higher than, that of boiling water. The high temperature, the lack of oxygen and the abundance of carbon dioxide can be interpreted as indications that there cannot be any great amount of vegetation on Venus and suggest that the planet is not the abode of life.

Mars occupies a position between Mercury on the one hand and Venus and the Earth on the other, as regards size, mass and velocity of escape. The velocity of escape is 5·0 km./sec., about one-half of the velocity of escape from Venus. It may be expected that Mars will have a much thinner atmosphere than Venus or the Earth. The presence of an atmosphere on Mars can be proved by photographing the planet in light of different colours. Photographs in the infra-red show permanent markings, which are evidently surface features, whereas photographs in the ultra-violet show none of these. By photographing

through filters which pass a narrow spectral region, it is found that the surface details become more and more distinct as the wave-length of the light increases. The atmosphere is extensive enough to scatter ultra-violet light to such an extent that the light cannot penetrate to the surface and out again.

The images obtained with ultra-violet light are larger than those obtained with infra-red light and the difference in size indicates that the atmosphere extends to a height of fully fifty miles above the surface.

The polar caps provide additional evidence of an atmosphere on Mars. As the summer advances over one hemisphere the polar cap gradually shrinks and disappears whilst the opposite cap, with the advance of winter, forms and grows. These changes are to be explained by the melting or deposition of ice, snow or hoar-frost, for the temperature is not low enough for the caps to consist of solid carbon dioxide. From the rate at which the caps decrease as summer advances it can be calculated that they are not more than a few inches thick, so that the whole quantity of water contained in them would be sufficient to make a lake of only moderate size. The caps are more prominent in ultra-violet than in infra-red photographs and are therefore partially atmospheric ; in winter, there is a permanent cloud layer above the pole.

Photographs by Wright, at the Lick Observatory, in light of different colours have given further confirmation of an atmosphere in the occurrence of clouds. The clouds are of two different types. One type of cloud is most prominent in the ultra-violet photographs. Such clouds must occur fairly high up in the atmosphere and must be sufficiently thin to allow the infra-red light to pass through ; these clouds have a tendency to begin to form at about Martian noon and to grow during the afternoon. It is probable that they are produced by the condensation of water-vapour, with the fall of temperature that begins at noon. The second type of cloud is seen on the infra-red, but not on the ultra-violet photographs. Such clouds appear yellowish to the eye. They must be at a fairly low level in the atmosphere and the yellowish hue is no doubt caused by atmospheric absorption.

All attempts to detect oxygen in the atmosphere of Mars have been unsuccessful. It can be concluded that the amount of oxygen is not more than one-thousandth part of the amount in the Earth's atmosphere. The red colour of Mars, which is unique among the heavenly bodies, provides indirect evidence of oxygen, suggesting rocks that have been completely oxidised. We may contrast the colour of Mars with the grey or brownish rocks of the Moon, which have not been oxidised. It appears probable that Mars may be a planet where the weathering of the rocks, followed by their oxidation, has resulted in the almost compete depletion of oxygen from the atmosphere.

The amount of water-vapour in the atmosphere of Mars is so small that it can be detected only under the most favourable conditions. At the Lowell Observatory, which is at an altitude of 7,250 feet, Slipher, in 1908, by comparing the spectra of Mars and the Moon when at the same altitude under conditions of exceptional atmospheric dryness in the winter, found that the water-vapour absorptions were slightly stronger in the spectrum of Mars than in that of the Moon.

Carbon dioxide has not been detected in the Martian atmosphere, which is not surprising since carbon dioxide must be present in large quantity before the absorptions in the region of the infra-red available for investigation can be

detected. There is some evidence of the existence of vegetation on Mars. Seasonal changes in form and coloration of the dark areas, light green changing to a darker green, and then to yellow and brown, seem to be reasonably well established. The interpretation of these changes as due to the seasonal growth of vegetation is plausible. The presence of some carbon dioxide in the atmosphere may therefore be inferred. Mars appears to be a world in the state that the Earth will ultimately reach when the oxygen in the atmosphere will have been almost entirely exhausted by the progressive weathering and oxidation of the rocks.

The major planets, Jupiter, Saturn, Uranus and Neptune, may be considered together. They are large massive planets, of low mean density, whose visible disks are considerably oblate. Their masses range from 317 times the mass of the Earth, in the case of Jupiter, to 15 times the mass of the Earth, in the case of Uranus. The mean densities of Jupiter, Uranus and Neptune are not greatly different from that of the Sun, which is 1·4 times the density of water ; Saturn has the lowest mean density of any of the planets, only seven-tenths that of water. The velocities of escape from all the major planets are so high, from 21 km./sec. to 60 km./sec., that extensive atmospheres are to be expected containing an abundance of the light constituents, hydrogen and helium, which have been lost from the atmospheres of the medium-sized planets.

The telescopic appearance of Jupiter and Saturn confirms the existence of dense atmospheres. Markings in the form of belts parallel to the equator may be seen ; these are of complex structure and their details are continually changing. Photographs in the infra-red show many differences from those in the ultra-violet, due to the greater penetration of the long-wave radiations into the atmosphere, but again the recorded features are continually changing, so that the infra-red light does not penetrate to the surface. Uranus and Neptune are too distant for detailed study of their surfaces, though faint belts parallel to the equator may be seen on Uranus.

Some theoretical results of interest have been obtained from the oblateness of these planets and the changes in the orbits of their satellites produced by the equatorial bulges of the parent planet. From investigations of this nature, Jeffreys concluded that these planets consist of a core of rock, generally similar to the inner planets in its constitution and of about the same mean density, surrounded by ice-coatings of great depth, above which are very extensive atmospheres. If these conclusions are accepted, some inferences may be derived about the thickness of the ice-coating and the depth of the atmosphere.

According to the calculations by Wildt, the rocky core of Jupiter has a radius of about 22,000 miles, so that it occupies only one-eighth of the whole volume corresponding to the visible disk ; the ice-coating is 16,000 miles in thickness and the depth of the atmosphere is about 6,000 miles. The rocky core of Saturn is about 14,000 miles in radius ; it is covered with a layer of ice some 6,000 miles thick, over which is an atmosphere extending to a height of 16,000 miles. The total weight of the atmosphere of Saturn is about equal to that of the rocky core. Saturn has the most extensive atmosphere of any of the planets, which explains why it has the lowest mean density and the most flattened disk of any planet.

The pressures of these extensive atmospheres are very great ; at the bottom of Jupiter's atmosphere, for instance, the pressure is fully a million times the

pressure at the bottom of the Earth's atmosphere. At a relatively small depth in the atmosphere, the pressure is great enough to compress the gas to a density nearly equal to that of the corresponding liquid. It is stated by Wildt that at the bottom of the atmospheres the pressure is great enough to solidify even the permanent gases.

The densities of the atmospheres are low ; according to Wildt's calculations they are 0·78 for Jupiter and 0·41 for Saturn. This enables most of the possible constituents to be excluded, for all known gases, in the liquid or solid state, have densities exceeding 0·3, with the exceptions of hydrogen and helium. Frozen oxygen, for instance, has a density of 1·45 ; nitrogen 1·02 ; ammonia, 0·82. In addition to helium and hydrogen, the only gases whose densities in the liquid or solid state are less than the density of the greater portion of the atmosphere of Jupiter are the hydrocarbons, methane, and ethane. There seems to be no escape from the conclusion that the atmospheres of the major planets must contain large quantities of free hydrogen and helium. This conclusion is in accordance with expectation. The planets are believed to have been formed in some way or other from the Sun, which is known to contain a large amount of hydrogen, to the extent of about one-third part by weight. Helium, oxygen, carbon and nitrogen are abundant in its outer layers. Massive planets, like the four major planets, would retain their light constituents ; hydrogen and helium are therefore to be expected to be present in large amount in their atmospheres.

The spectra of the major planets are of great interest. In the early days of spectroscopy Huggins discovered visually a strong absorption band in the orange and several weaker bands in the green in the spectrum of Jupiter. These bands appear more strongly in the spectrum of Saturn, but are not found in the spectrum of the rings—a conclusive proof that they originate in the atmosphere of Saturn. Uranus and Neptune show for the most part the same bands with still greater intensity, together with some additional ones. The great increase in the selective absorption from the yellow into the red and infra-red from Jupiter to Neptune accounts for the green colour of Uranus and Neptune ; most of the red and yellow regions of their spectra are lost by absorption. The investigations of Slipher during recent years have extended the spectra far into the infra-red to beyond λ 10,500 and have revealed several intense bands in that region.

The origin of these bands remained unknown until a few years ago. They had never been observed in the laboratory. Then Wildt succeeded in proving from theoretical investigations that certain of the bands agreed in position with bands of ammonia and that others agreed in position with bands of methane or marsh-gas. These theoretical conclusions were confirmed by Dunham, who, with the 100-inch telescope using much higher dispersion than had been available to Slipher, was able to obtain a more complete resolution of the bands into their component lines and found a complete coincidence. Dunham estimated that the quantity of ammonia gas producing the absorptions in the spectrum of Jupiter is equivalent to a layer 30 feet thick under standard conditions. The amount is less in Saturn. The ammonia absorptions are not detected in the spectra of Uranus and Neptune.

Methane is present in much larger amount. Adel and Slipher, in 1935, found that a 45-metre path of methane, at a pressure of 40 atmospheres, gave

bands intermediate in intensity between those of Jupiter and Saturn. The much greater strength of the methane absorptions in Uranus and Neptune is probably accounted for by the lower temperatures of these planets. The ammonia must be frozen out of their atmospheres, making it possible to see through them to a greater depth. Adel and Slipher estimated that 25 miles of methane at atmospheric pressure would be required to give absorptions as strong as those of Neptune.

The higher gaseous hydrocarbons, ethane, ethylene and acetylene, have been looked for in vain in the spectra of the outer planets. All the absorption bands appear to be accounted for by ammonia and methane. It is a grand slam.

The presence of ammonia and methane in the atmospheres of the large planets is not surprising. It is to be expected as a consequence of the large amount of hydrogen in the atmospheres. The picture, as painted by Russell, of the successive developments is as follows. When the major planets were hot, the hydrogen and helium were mixed with water-vapour, nitrogen and carbon dioxide. When the temperature fell below about 300° C., the carbon dioxide reacted with some of the hydrogen to produce methane and water-vapour, the partially reduced oxides of iron on the rocky surface exposed to hot hydrogen acting as a catalytic agent. With further cooling, at about the temperature at which the moisture began to condense, the free nitrogen would react with hydrogen to produce ammonia. There would then be an atmosphere of hydrogen, helium and other inert gases, mixed with methane, ammonia and water-vapour, but with little or no carbon dioxide or free nitrogen. Below this there would be a deep ocean, strongly alkaline from the ammonia in solution. As the temperature fell still further, the ocean would freeze. It may be mentioned that an ocean consisting of one part of ammonia to two parts of water would freeze at — 100° C. ; all the four major planets are colder than this. The only constituents in the atmospheres that are capable of detection are ammonia and methane.

It used to be thought that the rapid changes shown by the markings on Jupiter were indications that the planet was hot. It was believed that it still retained a great amount of its original heat. The theoretical considerations of Jeffreys and the direct measurement of the temperature of Jupiter—which give a value of about — 135° C.—have shown that Jupiter must be intensely cold. The presence of ammonia and methane in its atmosphere provides further confirmation, if any lingering doubt remains, for, if Jupiter were hot, these gases would be dissociated. The ultra-violet radiation from the Sun gradually breaks up the molecules both of ammonia and of methane even at low temperatures. In the absence of oxygen, the break-up is followed by a natural recombination. From the quantity of ammonia observed to be present in the atmosphere of Jupiter, Dunham has concluded that the temperature cannot be lower than about — 120° C., if there is a large excess of hydrogen in the atmosphere. This is in close agreement with the directly observed value.

The ammonia in the atmospheres of Jupiter and Saturn must be nearly on the point of condensation and the clouds over these planets may consist of droplets of liquid ammonia or even small crystals of frozen ammonia.

The mean temperatures of Uranus and Neptune due to solar radiation

alone are about — 200° C. and — 220° C. respectively. At the temperature of Neptune the methane must be nearly ready to condense.

The nature of the planetary atmospheres, about which so little was known until recently, seems now to have been solved in its broad outlines. There are many details still not understood, such as the nature of the disturbances that continually occur in the atmosphere of Jupiter, and the cause of the colorations ; and it still remains a puzzle whether there is water or water-vapour on Venus. As a brief summary we find that we can divide the planets and their satellites into three groups : the small ones, entirely devoid of atmospheres ; the middle-sized ones, with atmospheres of moderate extent, devoid of hydrogen or hydrogen compounds but containing oxygen or compounds of oxygen ; and the large ones, with very extensive atmospheres devoid of oxygen or compounds of oxygen but containing hydrogen and compounds of hydrogen.

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